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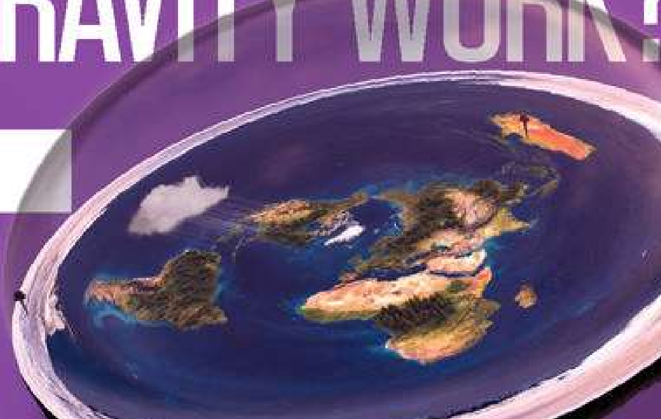

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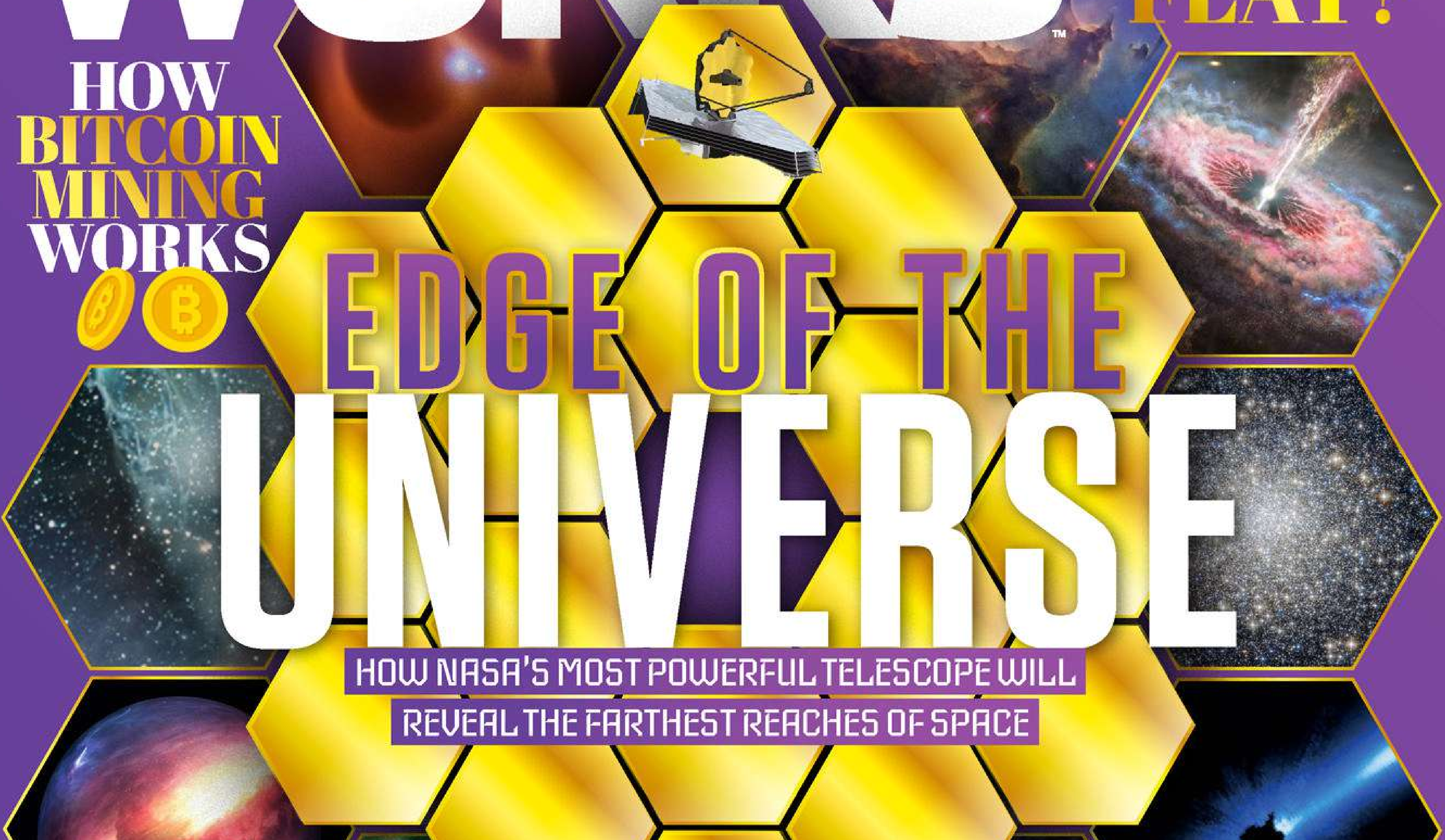

EDGE OF THE UNIVERSE

HOW NASA'S MOST POWERFUL TELESCOPE WILL REVEAL THE FARTHEST REACHES OF SPACE

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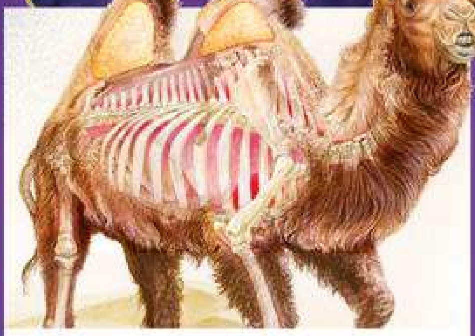
WHY THE MAYA CIVILISATION COLLAPSED



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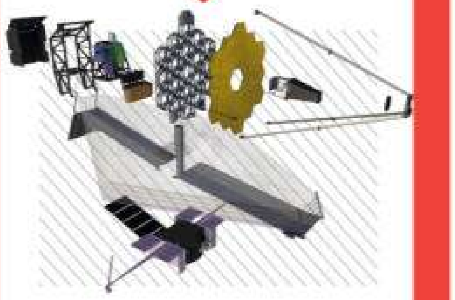
WELCOME

Issue 158

“If you can name it, Webb is likely to observe it”

HIGHLIGHTS



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EDGE OF THE UNIVERSE

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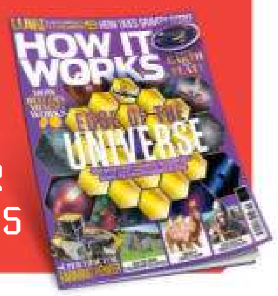
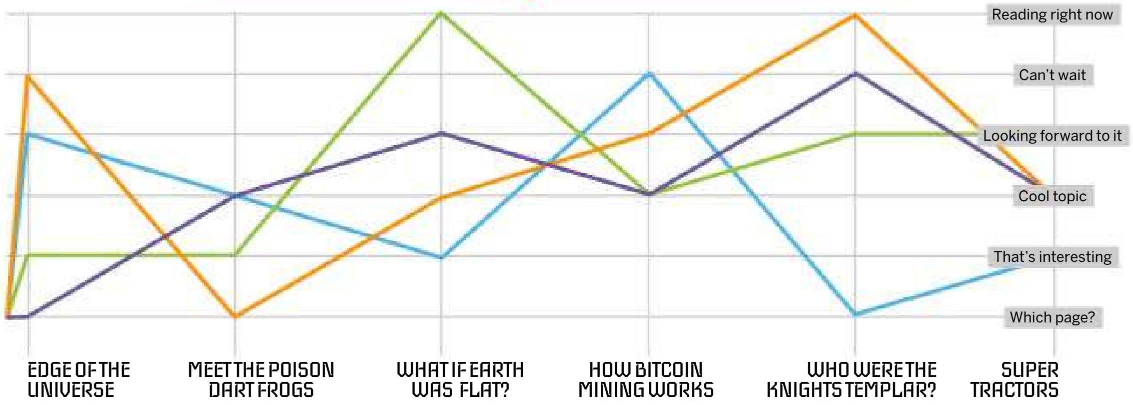


It's been one of astronomy's most anticipated projects, perhaps even generating more excitement than the Mars Perseverance rover: the James Webb Space Telescope has been billed as the successor to the Hubble Space Telescope. If everything goes according to plan, when it's been launched and placed in its Lagrange point orbit around a million miles from Earth, the veil will be lifted from the unexplored farthest reaches of the universe. In this issue of **How It Works**, discover the ingenious construction of the world's most powerful telescope, how it will use infrared light to take unprecedented images of the edge of space and what we can expect the telescope to reveal. Enjoy!

Ben Biggs

WHAT WE'RE ANTICIPATING



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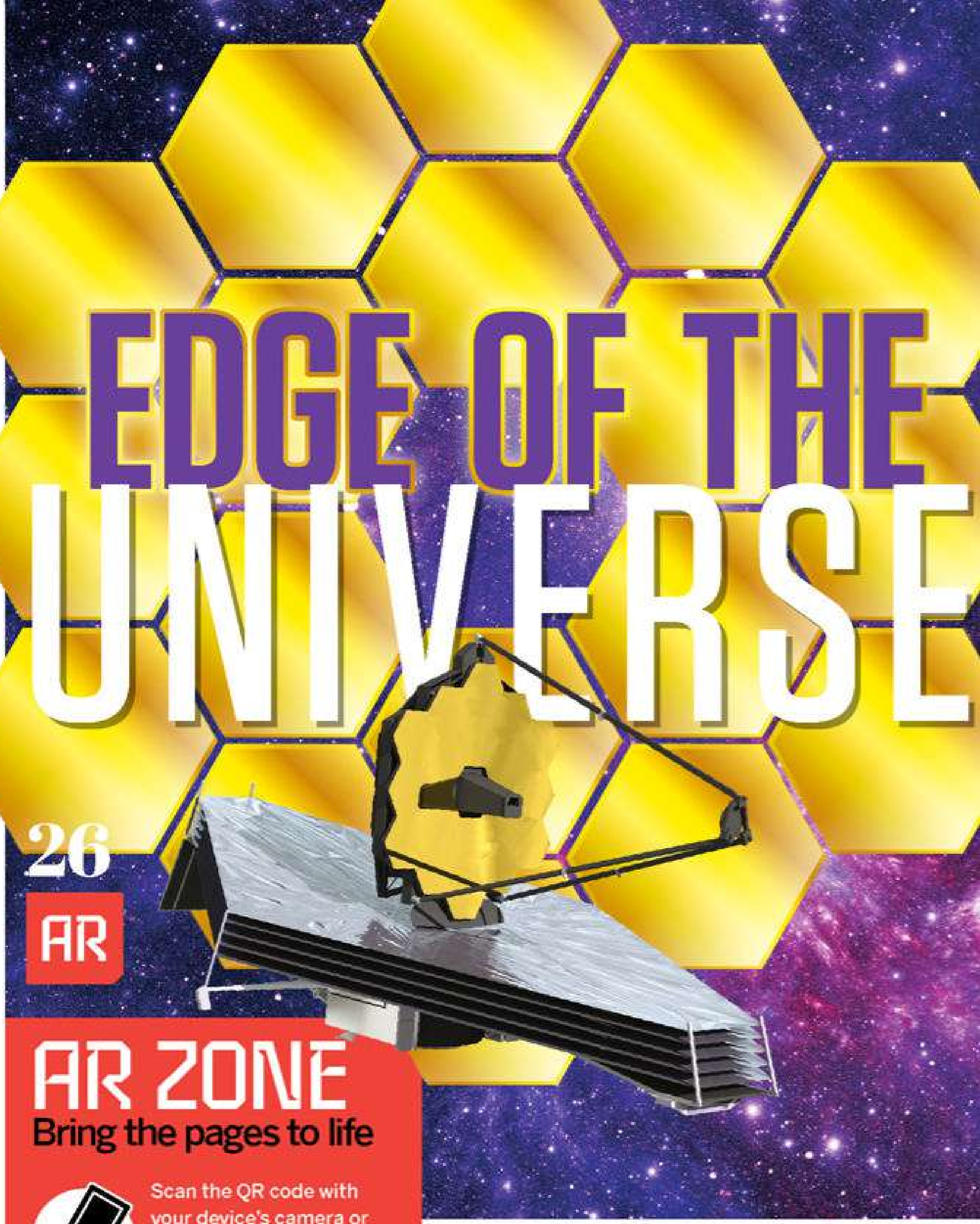

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MEET THIS ISSUE'S EXPERTS

ANDY EXTANCE

Andy is a science writer. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

DR ANDREW MAY

Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

VICTORIA WILLIAMS

Evolutionary biologist and science writer

Vicky is fascinated by the natural world and is happiest when she's in the outdoors.

JO ELPHICK

Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

MARK SMITH

A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

WIN

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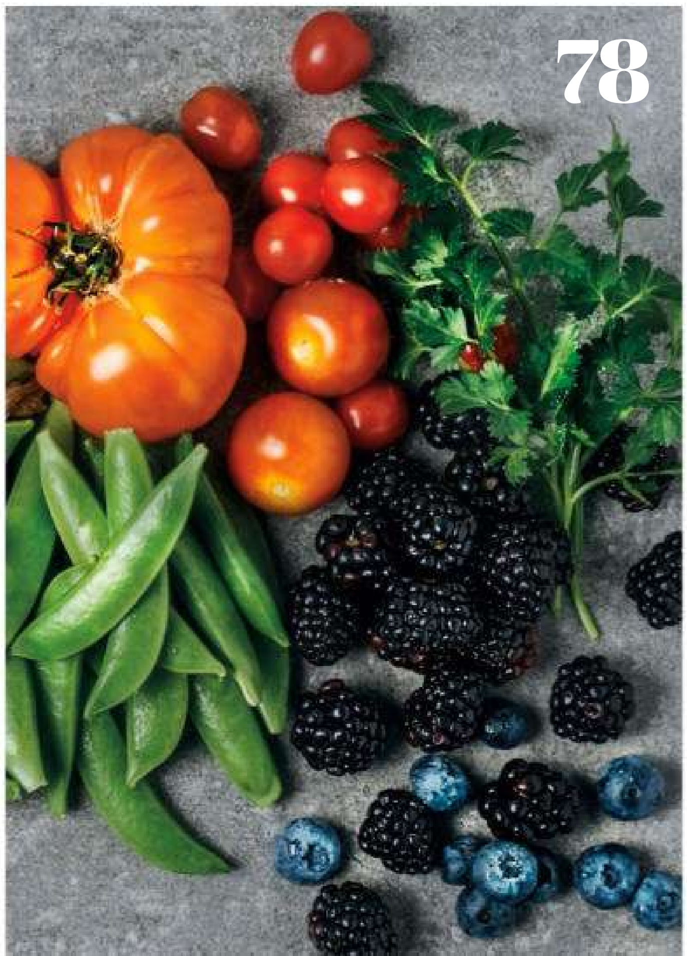

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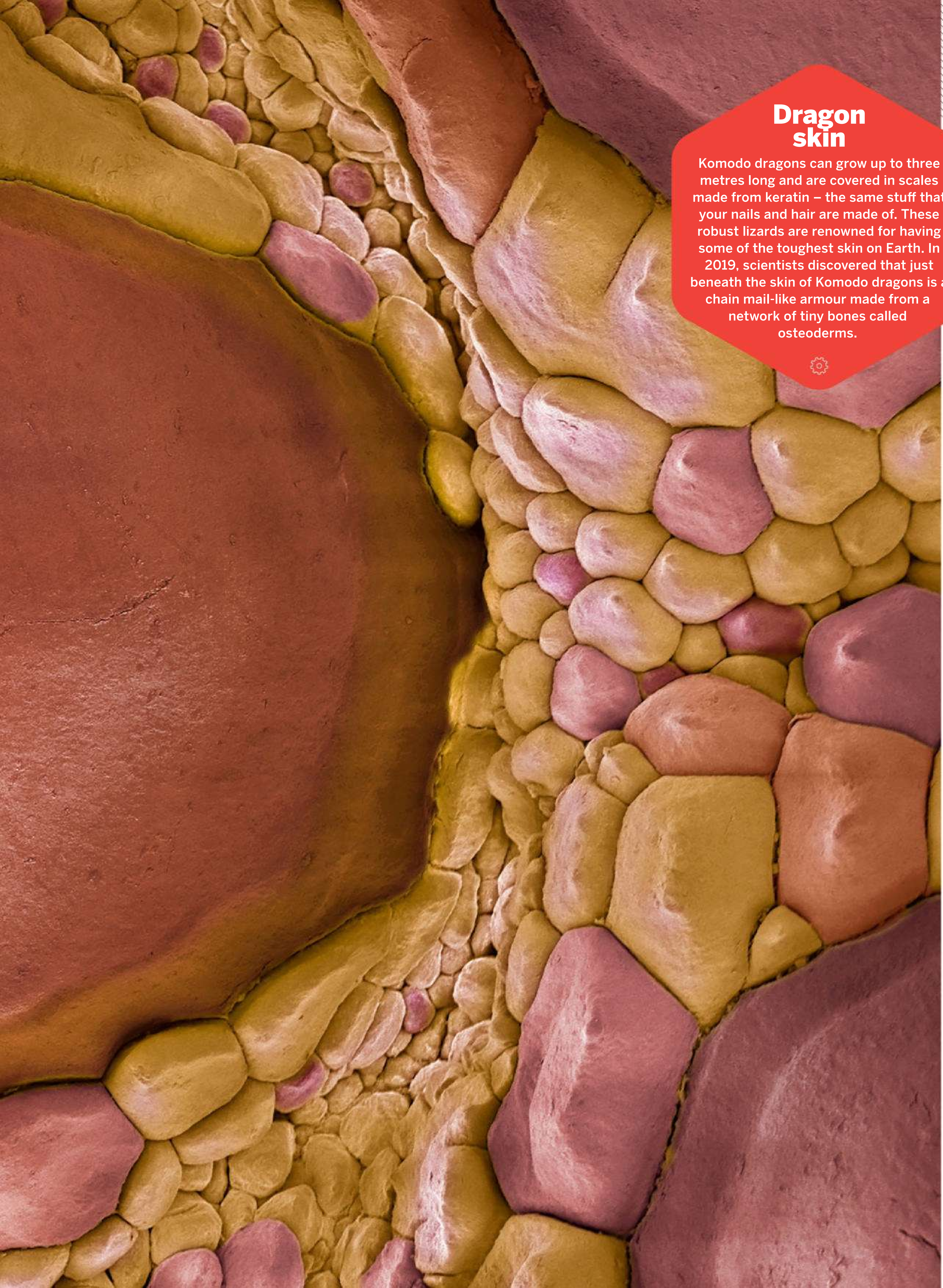

Dragon skin

Komodo dragons can grow up to three metres long and are covered in scales made from keratin – the same stuff that your nails and hair are made of. These robust lizards are renowned for having some of the toughest skin on Earth. In 2019, scientists discovered that just beneath the skin of Komodo dragons is a chain mail-like armour made from a network of tiny bones called osteoderms.

© Getty

Landsat liftoff

On 27 September 2021, Landsat 9 was launched from Vandenberg Space Force Base in California. This image shows the immense force generated by the engine aboard an Atlas V rocket. The rocket's main RD-180 engine burns liquid oxygen and kerosene to generate an initial thrust of about 390 tonnes. Once airborne, the Atlas V rocket accelerates at supersonic speeds of around 10,000 miles per hour.

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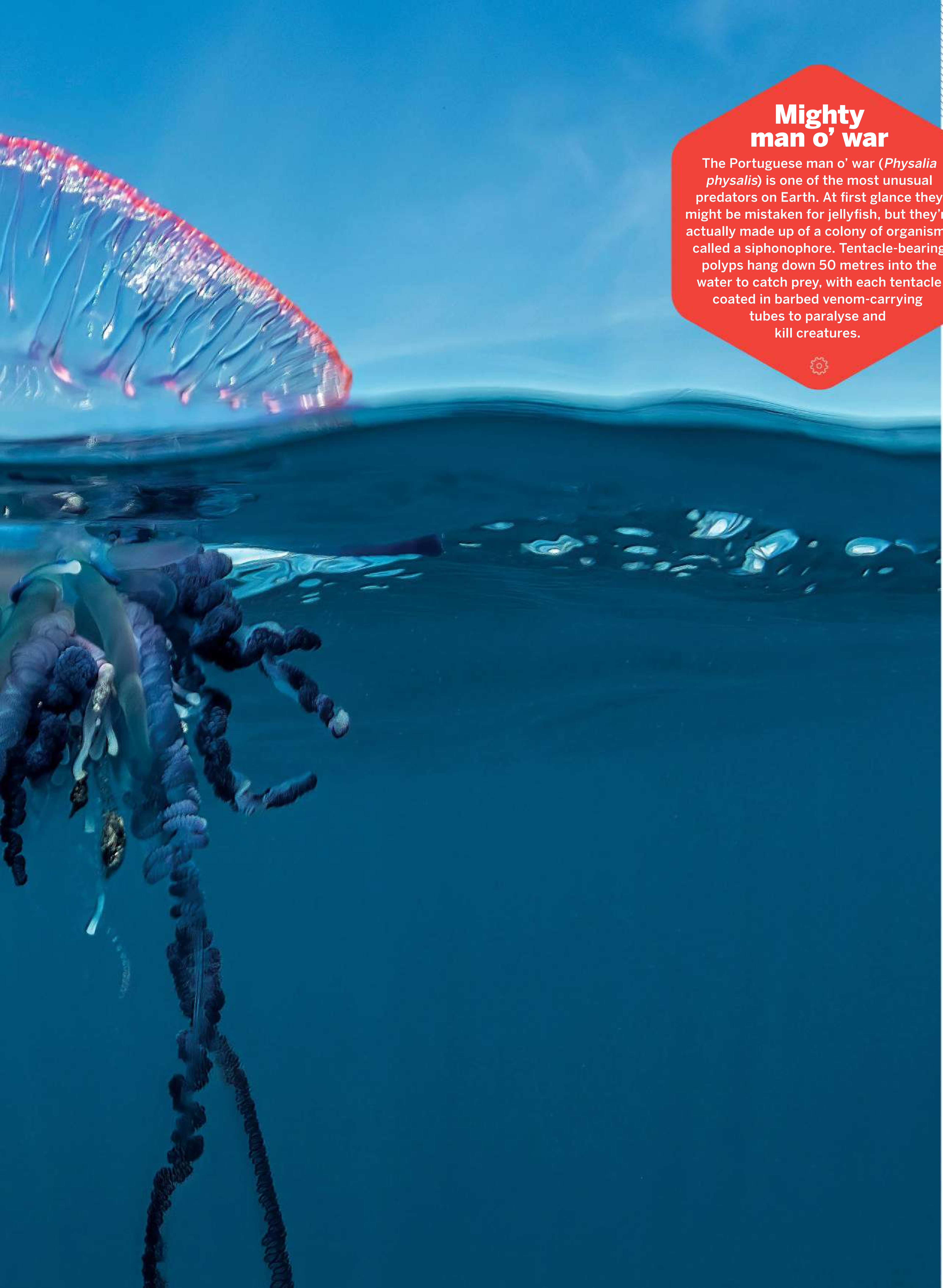

Mighty man o' war

The Portuguese man o' war (*Physalia physalis*) is one of the most unusual predators on Earth. At first glance they might be mistaken for jellyfish, but they're actually made up of a colony of organisms called a siphonophore. Tentacle-bearing polyps hang down 50 metres into the water to catch prey, with each tentacle coated in barbed venom-carrying tubes to paralyse and kill creatures.

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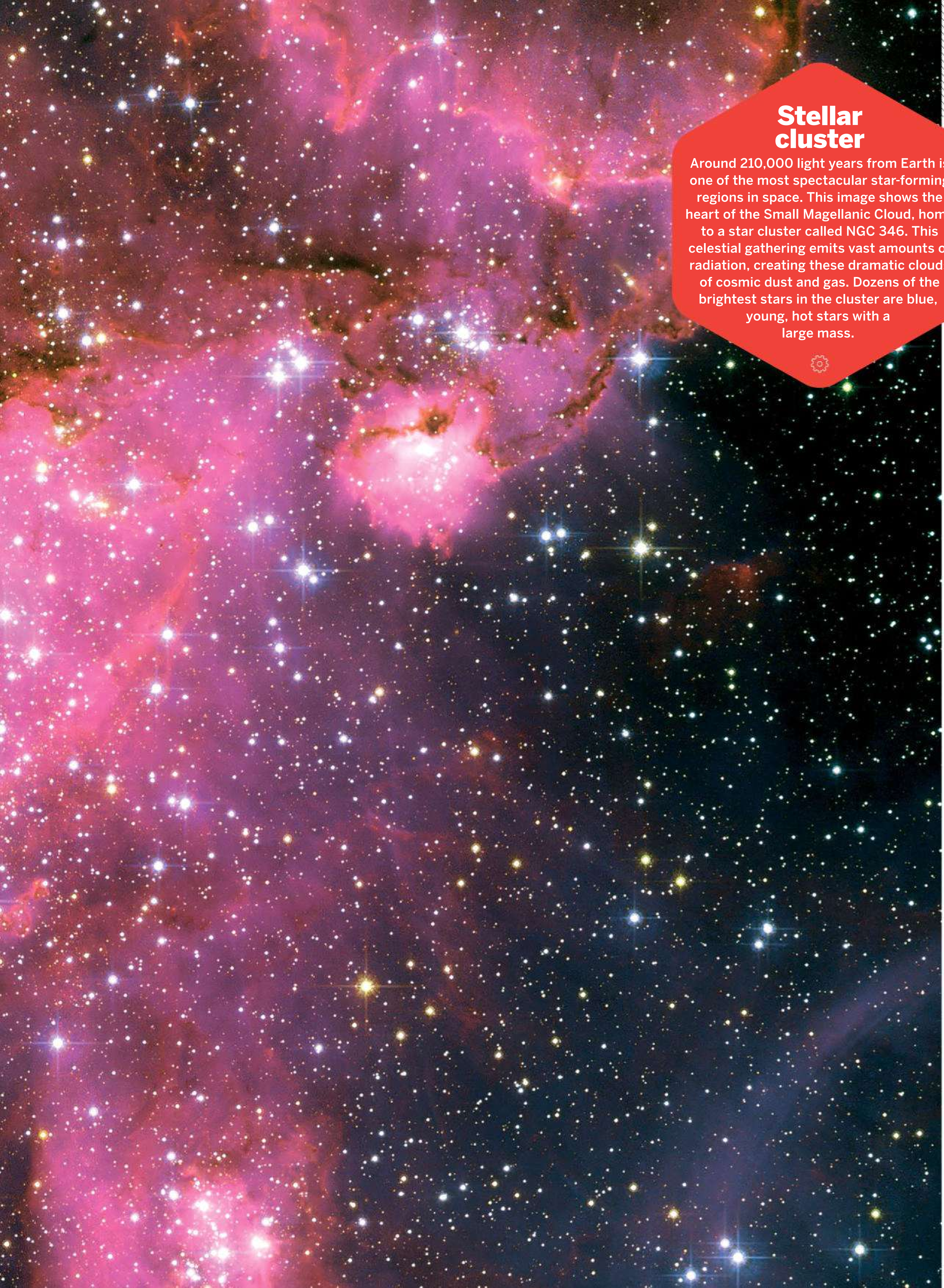

Stellar cluster

Around 210,000 light years from Earth is one of the most spectacular star-forming regions in space. This image shows the heart of the Small Magellanic Cloud, home to a star cluster called NGC 346. This celestial gathering emits vast amounts of radiation, creating these dramatic clouds of cosmic dust and gas. Dozens of the brightest stars in the cluster are blue, young, hot stars with a large mass.

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Critically endangered California condors (*Gymnogyps californianus*) can reproduce asexually

ANIMALS

Condor chicks have 'virgin births'

WORDS **MINDY WEISBERGER**

Scientists have reported the first known 'virgin births' in California condors: two chicks that hatched without any males involved in fertilising the eggs. Researchers recently made the unexpected discovery that the genomes of these two birds contained no DNA from any condor males. This made the two fatherless condors rare examples of a type of asexual reproduction called parthenogenesis.

During parthenogenesis, spontaneous embryonic development occurs without fertilisation. It's rare, but not unheard of in reptiles and fish, and while scientists have documented parthenogenesis in domesticated birds such as turkeys and chickens, this is the first example of a 'virgin birth' producing viable chicks in a population of wild condors. Discovering this male-free reproductive strategy in California condors (*Gymnogyps californianus*) is significant because just a few decades ago the species came dangerously close to vanishing from the wild.

In the 1980s, fewer than two dozen condors remained in the wild, but dedicated conservation efforts and breeding programs brought condors back from the brink of extinction. As of 2020, there were 504 condors, of which 329 were wild and 'free flying'. However, the species is still considered to be critically endangered. Finding that condors can reproduce asexually – potentially increasing the species' chances of producing offspring – is therefore a pretty big deal.

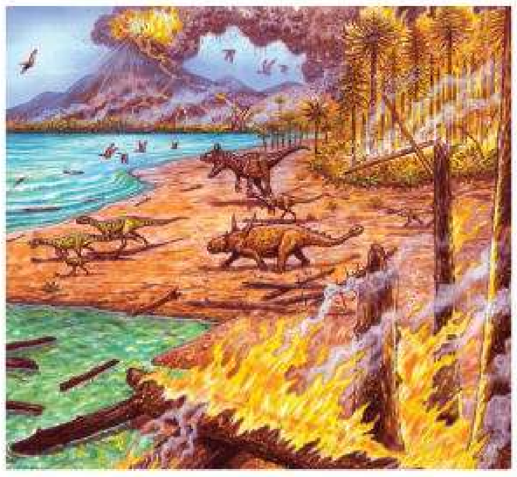
For the past 30 years, researchers have catalogued DNA data from every California condor – more than 1,000 birds in all – compiling that information into a database. Scientists who work with the condors conduct genetic analyses of the birds routinely to determine relationships, enabling them to breed condors so that the population maintains genetic diversity. This approach helps to prevent inbreeding and the development of inherited disorders such as condor dystrophy, "which is characterised by malformations in the embryos and late-embryonic mortality," said Cynthia Steiner, associate director in conservation genetics at the San Diego Zoo Wildlife Alliance.

But when the researchers analysed the genotypes of two male condors in the database, which had been released into the wild but are now deceased, they noticed something extremely unusual: genetic information in the two birds matched up only to the females that hatched them. According to the database, no male qualified as a potential sire.

"When animals reproduce sexually, females and males contribute to the genetic makeup equally. But in these two condors, we couldn't find any contribution coming from any male we had in our database," Steiner said. "That was a red flag." One possibility that the scientists considered was an error in the birds' genetic tests, so they repeated the process. The results didn't change.

"At that point, it was like a eureka moment when we figured out that parthenogenesis was a possibility," Steiner said. "The only way that we could explain the genotypes of these two individuals was by having a contribution that is 100 per cent from the female, with no paternal contribution."

Condor chicks born via parthenogenesis would be male-only. That's because only two matching sex chromosomes can be formed during this type of asexual reproduction. And in condors, it's the females that have the mismatched sex chromosomes. "Different sex-determination chromosomes are used in birds and humans: the XX/XY (female/male) system in humans versus the ZW/ZZ (female/male) in birds," Steiner said. When the mother condor fertilises her own eggs, the resulting offspring all have ZZ chromosomes – WW is not a viable match up. The mothers of these two birds had produced multiple chicks over time via sexual reproduction, but further study would be required to determine the factors that led them to reproduce asexually.



Dinosaurs attempt to flee a wildfire on Antarctica during the Late Cretaceous

HISTORY

WILDFIRES BURNED ANTARCTICA 75 MILLION YEARS AGO

WORDS **LAURA GEGGEL**

Raging wildfires tore through Antarctica 75 million years ago, back when dinosaurs still roamed the Earth. During the Late Cretaceous Period, one of the warmest periods on Earth which ran from 100 million to 66 million years ago, Antarctica's James Ross Island was home to a temperate forest of conifers, ferns and flowering plants known as angiosperms, as well as to a slew of dinosaurs. But it wasn't a total paradise; ancient 'paleofires' burned parts of those forests to a crisp, leaving behind charcoal remnants that scientists have now scooped up and studied.

In 2015, researchers documented the first known evidence of dinosaur-age wildfires in West Antarctica. For the recent work, an international team of scientists analysed fossils collected during an expedition to James Ross Island. These fossils contained fragments of plants that looked like charcoal residue, which had weathered away over the past tens of millions of years. The charcoal fragments were small – the largest paper-thin pieces were just 19 by 38 millimetres. But scanning electron microscope images revealed their identity. These fossils are likely burned gymnosperms, likely from a botanical family of coniferous trees called Araucariaceae.

SPACE

Jupiter's Great Red Spot is over 200 miles deep

WORDS **BRANDON SPECKTOR**

On Jupiter, a storm's been brewing for more than 300 years. Known as the Great Red Spot (GRS), this swirling high-pressure region is clearly visible from space, spanning a region in Jupiter's atmosphere more than 10,000 miles wide – about one-and-a-quarter times the diameter of Earth. But there's even more to the churning tempest than meets the eye. Recent research has revealed that Jupiter's Great Red Spot is also extraordinarily deep, extending as many as 300 miles into the planet's atmosphere, or about 40 times as deep as the Mariana Trench on Earth.

That's far deeper than researchers expected, with the bottom of the storm extending well below the atmospheric level where water and ammonia are expected to condense into clouds. The storm's deep roots suggest that some as-yet unknown processes link Jupiter's interior and deep atmosphere, driving intense meteorological events over much larger scales than previously thought. "We're getting our first real understanding of how Jupiter's beautiful and violent atmosphere works," said Scott Bolton, principal investigator of NASA's Juno mission.

NASA's Juno probe entered Jupiter's orbit in 2016 and has since completed 36 passes of the nearly 87,000-mile-wide gas giant. Researchers examining the Great Red Spot used the probe's microwave radiometer, a tool that detects microwaves emitted from inside the planet. Unlike the radio and infrared radiation emitted by the gas giant, microwaves can make it all the way through the planet's thick cloud layer.

By studying the microwave emissions that made it through the Great Red Spot, the researchers have determined that the storm extends more than 200 miles deep. It has also been discovered that the spot may be even bigger than that. The Great Red Spot was examined using Juno's gravity-detection tools. Using the data from 12 flights that passed by the spot, researchers have calculated where the storm was concentrating the most atmospheric mass over the planet, allowing them to estimate its depth. Researchers have determined that the spot reaches a maximum depth of about 300 miles below the cloud tops.

As deep as this seems, the Great Red Spot is still much shallower than the enormous jets of wind that surround and power it; those bands of wind extend to depths of about 2,000 miles below the cloud tops.

Did you know?
The GRS could be more than 350 years old

An image of Jupiter's Great Red Spot using data from the JunoCam imager on NASA's Juno spacecraft

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Research revealed that pupils expand when there are more objects to look at

HEALTH

Your pupils can count... sort of

WORDS **YASEMIN SAPLAKOGLU**

The pupils of your eyes might be able to count, in a manner of speaking. Recent research suggests pupil size can change based on the number of objects an individual observes in their visual field. Pupils are holes located in the centre of the eye which change size to regulate the amount of light that enters the eye based on how much is available in the environment. The response of our pupils to light is a basic sensory response, but pupils have been found to change size based on factors other than light, such as arousal.

Researchers hypothesised that pupils may also change size based on the number of objects that a person sees in their environment. It's thought that most species have a certain "number sense", said study coauthor David Burr, a professor at the University of Sydney and the University of Florence. Previous research has suggested that humans may develop a 'crude number discrimination' as soon as a few hours after birth.

"When we look around, we spontaneously perceive the form, size, movement and colour of a scene. Equally spontaneously, we perceive the number of items before us," Burr said. "This ability, shared with most other animals, is an evolutionary fundamental. It immediately reveals important quantities, such as how many apples there are on the tree, or how many enemies are attacking."

To figure out if this ability lies within the pupils, the researchers presented 16 adult participants with images of dots on a monitor in an otherwise quiet, dark room. As the participants stared at the screen, without being asked to count the dots, a machine measured their pupil sizes. The images contained either 18 or 24 black or white dots, and each dot was either separate or coupled up with a small line, giving the person the illusion that there were fewer dots on the monitor than there actually were.

The researchers found that the size of the participants' pupils changed depending on how many dots they perceived. The participants' pupils dilated, or expanded, when they perceived a greater number of dots and constricted when they perceived fewer dots.

The findings suggest that the pupil is equipped with some mechanism that can sense quantity. "This result shows that numerical information is intrinsically related to perception," said Elisa Castaldi, a postdoctoral researcher at the University of Pisa. "This could have important practical implications."

For example, similar methods could be employed to detect dyscalculia, a learning disability that makes people have trouble doing maths, in very young children. "It's very simple: subjects simply look at a screen without making any active response, and their pupillary response is measured remotely," Castaldi added.

SPACE

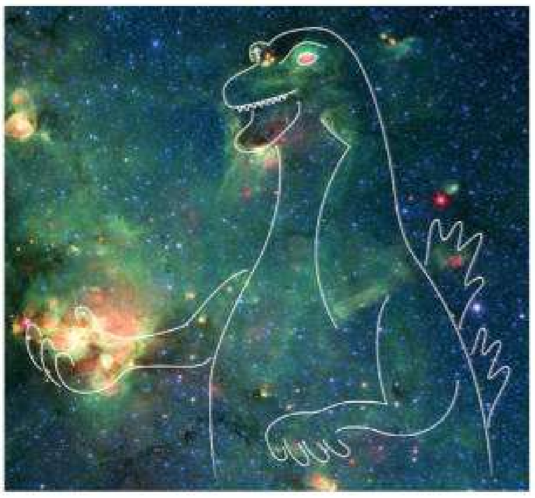
GODZILLA NEBULA LOOKS LIKE A SPACE LIZARD

WORDS **STEPHANIE PAPPAS**

What do you see in this image of space gas and dust? Perhaps the greenish blob puts you in mind of a frog, a crocodile or even Slimer from *Ghostbusters*. One scientist is pretty sure he saw Godzilla. Much like clouds on Earth, space clouds can trigger pareidolia, the recognition of a face or familiar object in an ambiguous pattern. And the Godzilla nebula – which sort of looks like the space lizard, but potentially like any other number of objects – is a prime example of the phenomenon.

"I wasn't looking for monsters," said Caltech astronomer Robert Hurt, who catalogues images from NASA's Spitzer Space Telescope. "I just happened to glance at a region of sky that I've browsed many times before, but never zoomed in on. Sometimes if you just crop an area differently, it brings out something that you didn't see before. It was the eyes and mouth that roared 'Godzilla' to me."

This space monster is actually in the constellation Sagittarius. The stars that make up Godzilla's nose and eyes are within the Milky Way, though their distance from Earth isn't known. The bright region to the lower left, which Hurt imagines as Godzilla's outstretched claw, is a star-forming region called W33.



Pareidolia tricked an astronomer into seeing Godzilla in this Spitzer image of a cloud of dust and gas

ANIMALS

Great white sharks mistakenly identify humans as prey

WORDS **PATRICK PESTER**

A great white shark with its jaws open at the surface off southern Australia

Great white sharks can't see the difference between their typical prey and humans swimming or paddling on surfboards, suggesting some shark attacks are cases of mistaken identity. Researchers filmed seals and humans in water and edited the footage so that it matched the vision of juvenile great white sharks, which pose the greatest risk to human surfers. They found that the shape and motion of humans look the same as seals from a shark's perspective. The study is the first to test the theory that sharks attack humans because they mistake people for prey.

"White sharks are often portrayed as 'mindless killers' and 'fond of human flesh'. However, this doesn't seem to be the case – we just look like their food," said Laura Ryan, a neurobiologist and postdoctoral researcher at Macquarie University in Australia.

Great whites (*Carcharodon carcharias*) are responsible for more human deaths than any other shark species and killed six people in 2020, although the relative risk of humans being bitten by sharks is still extremely low. These sharks start hunting seals when they are about 2.5 metres long. They develop a search image for their prey and combine that with other sensory information, such as smell, to know what to eat. It's a learning process that could be prone to mistakes. Great white sharks lack colour vision and cannot see fine details like the human eye can. The researchers processed the videos they filmed to reflect how a shark's retina detects the motion and shapes of seals and compared that motion to humans swimming and paddling on surfboards. This included a longboard (2.83 metres by 0.58 metres) and shortboard (1.77 metres by 0.5 metres) surfboard. They concluded that none of the scenarios were visually distinct for a juvenile great white shark swimming below.

"I knew there would be some similarities, but maybe not to the extent we found," Ryan said. "Specifically, I thought swimmers might not be as similar as a surfer to a seal, as they typically aren't involved in as many shark bites. However, the swimmers were also difficult to tell apart from a seal."

The longboard surfboard was less similar to seals, indicating there are some small differences in the way a great white shark might perceive the shape of longboard surfboards compared to shortboard surfboards and swimmers. However, the researchers don't know how that is reflected in shark behaviour because sharks bite humans on longboards too.

The new research only applies to great white sharks, and there are other sharks, such as bull sharks and tiger sharks, that also occasionally bite humans. Furthermore, mature great white sharks also sometimes bite humans, and when they are older, more experienced hunters, they may make fewer mistakes. In other words, not all bites are necessarily due to mistaken identity.

Great whites are vulnerable to extinction, and humans deliberately kill them as part of beach-protection programs in Australia and South Africa, though sharks are sometimes captured and released. Not knowing why sharks attack humans creates public concern and leads to humans introducing measures to reduce shark populations, which also has harmful effects on other marine life. Sharks play important roles in ocean ecosystems; by hunting other animals, they ensure prey populations remain healthy and at a size their habitat's resources can support.

© Getty / NASA/JPL-Caltech

PLANET EARTH

Huge hole discovered in Arctic's 'last ice'

WORDS **STEPHANIE PAPPAS**

A huge hole opened in the Arctic's oldest, thickest ice in May 2020. Scientists previously thought that this area of ice was the Arctic's most stable, but the giant rift signals that the ancient ice is vulnerable to melt. The polynya, or area of open water, is the first to be observed north of Ellesmere Island. But researchers deduced from old satellite data that similar polynyas may have opened in 1988 and 2004.

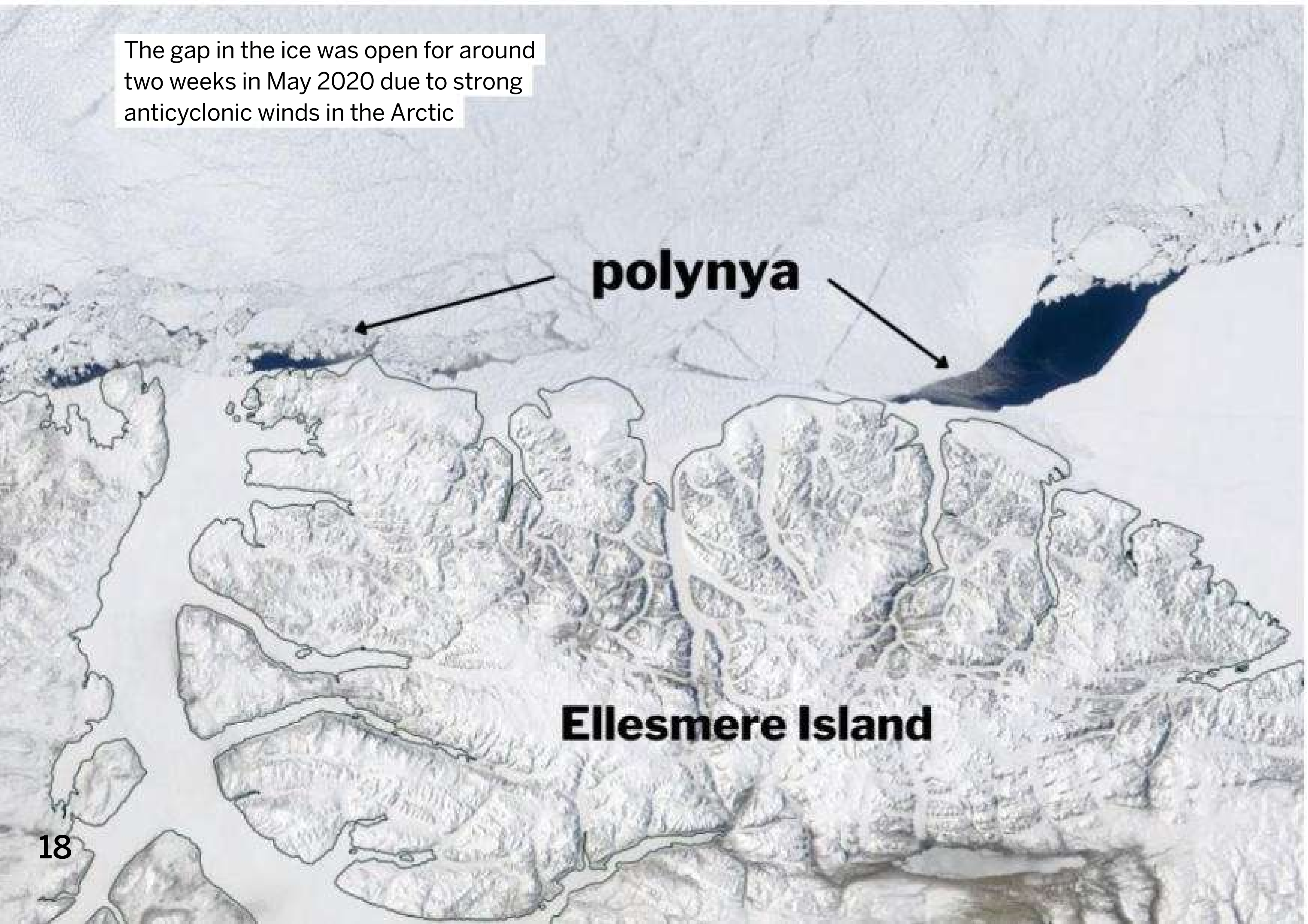
"North of Ellesmere Island it's hard to move the ice around or melt it because it's thick, and there's quite a bit of it," said Kent Moore, an Arctic researcher at the University of Toronto-Mississauga. "We generally haven't seen polynyas form in that region before." The sea ice off the northern coast is typically more than four metres thick and has an average age of five years. But this 'last ice' is proving vulnerable to the rapid warming occurring in northern latitudes. In summer 2020, the Wandel Sea, or the eastern reaches of the 'last-ice' region, lost half of its overlying ice. A 2021 study showed that the ice arches that connect the stable sea ice to Greenland are forming later and melting faster each year.

Now, researchers say that the last-ice area may melt completely each summer by the end of the century, spelling the end for animals that depend on year-round sea ice, such as polar bears. The polynya is another bad sign for the last ice. Polynyas are cracks in the sea ice that often open up during storms, when strong winds move the ice. There was a powerful storm north of Ellesmere Island in May 2020, and satellite imagery showed that a long narrow crack, or lead, formed on 14 May. By 15 May the lead had evolved into an elliptical polynya about 62 miles long and 18.6 miles wide. On 26 May the polynya rapidly closed.

"The formation of a polynya in the area is really interesting," said David Babb, a sea ice researcher at the University of Manitoba in Canada. "It's sort of like a crack in the shield of this solid ice cover that typically exists in that area. That this is happening is also really highlighting how the Arctic is changing." In the future, polynyas might open up more frequently as the Arctic's last ice melts, Moore said.

In the short term, these areas can be oases for life: sunlight hits the ocean water, allowing for more algal photosynthesis, which attracts fish and crustaceans. These animals attract seabirds, seals and polar bears, he added. But this explosion of life is only temporary.

Did you know? Greenland was discovered around 980 CE


The gap in the ice was open for around two weeks in May 2020 due to strong anticyclonic winds in the Arctic

HISTORY

SKELETON OF MAN FLEEING VESUVIUS ERUPTION DISCOVERED

WORDS **STEPHANIE PAPPAS**

The bones of a man who was unable to escape the eruption of Mount Vesuvius in 79 CE have been found in the ancient Roman town of Herculaneum. The skeletal remains were discovered near a stone wall along the ancient seafront, the first discovery of a Vesuvius victim in Herculaneum in 25 years. The bones belonged to a man in his early 40s. He may have died in the final phase of the eruption, when gas and ash rushed through the town at more than 60 miles per hour and around 500 degrees Celsius in a pyroclastic flow.

Researchers found the skeleton with its head towards the sea and surrounded by carbonised wood. A large roof beam found near the body may have crushed the man's skull. It's not clear who the man was or what he was doing when he died. He may have been a town resident who left a shelter to look for a rescue boat, only to be caught up in the devastating last moments of the eruption. Or he may have been a soldier with the rescue effort who ended up stranded among those he was trying to save.

The team now plans to remove the chunk of hardened ash that encases the victim's body and then excavate the skeleton in a laboratory environment. Fragments of metal and fabric near the skeleton may be a bag holding tools, weapons or coins. Investigating the contents of the bag could yield hints to his identity.

A view of excavations of the Roman town Herculaneum, buried by Vesuvius in 79 CE

SPACE

Alien planet 'aurorae' may send signals towards Earth

WORDS **BRANDON SPECKTOR**

Four brand-new alien planets have potentially been discovered after scientists detected the shimmering radio flashes of aurorae in those planets' atmospheres. Aurorae occur when the solar wind, intense gusts of electric particles belched out by the Sun, smash into a planet's magnetic shield. Earth experiences aurorae near the north and south poles, where miraculous displays of colour and light streak through the sky. But this pleasant light show is only a piece of the story; astronomers know that the cosmic clash of the solar wind and magnetic fields also produces bright flashes of radio light that can be seen far across the galaxy. To an alien observer hundreds of light years away, the aurorae of Earth may look like sudden, bright explosions of radio energy.

Scientists think they've discovered four planets within 160 light years of Earth by detecting the shimmering radio flashes of aurorae in those planets' atmospheres. If confirmed by future research, these four alien worlds will be the first planets detected through radio waves, potentially opening a new avenue for planetary detection in our galaxy. "It's a spectacle that has attracted our attention from light years away," said Joseph Callingham, an astrophysicist at Leiden University in the Netherlands.

The researchers discovered these potential planets somewhat accidentally while surveying nearby red dwarf stars with the Low Frequency Array (LOFAR) radio telescope in the Netherlands. Red dwarfs are much smaller, cooler stars than our Sun and are thought to be the most common type of star in the galaxy. These stars typically have very large magnetic fields, and tend to flare up with gigantic bursts of energy that are visible across the electromagnetic spectrum.

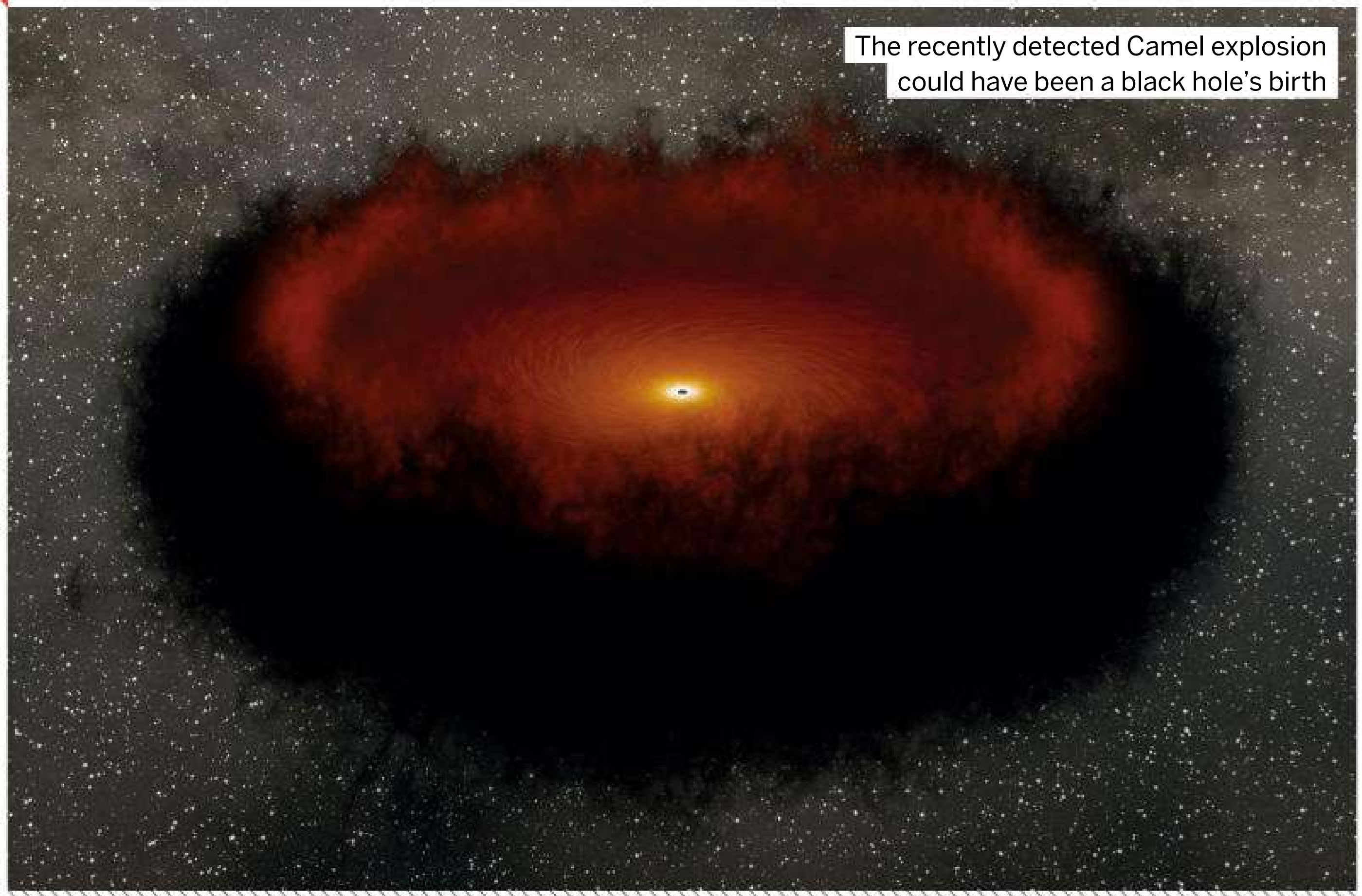
Of the 19 red dwarfs the researchers detected, four seemed a little unusual. These oddball stars appeared very old and magnetically inactive, yet they still shined with bright radio signals. If these signals weren't the result of large magnetic flare-ups, then what could be causing them? Using a mathematical model, the team concluded that the strange radio signals are most likely from a powerful auroral process occurring in the atmospheres of unseen, undiscovered planets orbiting the old stars. The process is similar to aurorae on Earth, with charged solar wind clashing with a magnetic field, but they may behave more like the powerful aurorae seen on Jupiter.

"Aurorae from Jupiter [are] much stronger, as its volcanic moon Io is blasting material out into space, filling Jupiter's environment with particles that drive unusually powerful aurorae," Callingham said. "Our model for this radio emission from our stars is a scaled-up version of Jupiter and Io." With radio data alone, the researchers can't be sure that hidden planets are responsible for the strange signals around these old stars. However, powerful planetary aurorae seem to be the most plausible explanation right now.

Further observations of the withered stars could reveal if the team's theory is correct, and whether bright blasts of radio energy can help lead astronomers to more alien worlds in the future.

A false-colour image showing the southern aurorae on Saturn

© Getty / NASA/JPL/University of Arizona/University of Leicester / NASA EOSDIS Worldview



The recently detected Camel explosion could have been a black hole's birth

SPACE

Ultrahot, ultrafast explosion has astronomers puzzled

WORDS **BRANDON SPECKTOR**

In October 2020, astronomers detected an enormous, ancient explosion tearing through a galaxy several billion light years from Earth. The blast appeared out of nowhere, reached peak brightness within a few days and then rapidly vanished again within a month, indicating that an extreme cosmic event, like the formation of a black hole or neutron star, had just occurred.

Astronomers call sudden, bright blasts like these fast blue optical transients (FBOTs), named for their extreme 'blue' heat and incredibly rapid evolution. But you can call this one 'the Camel'. That nickname – a play on the object's technical name, ZTF20acigmel – may seem unbefitting for a blast so fast and powerful, but such is the way of FBOTs. A similar explosion detected in 2018, roughly 200 million light years from Earth, earned the unlikely name 'the Cow' – the result of a procedurally generated scientific name – while another 2020 FBOT was dubbed 'the Koala', also a play on its technical name.

These three FBOTs are in a class of their own when it comes to stellar explosions. Unlike typical supernovae, the epic blasts that occur when stars run out of fuel and collapse, FBOTs seem to appear and disappear in a matter of weeks, rather than years.

But even after their visible light fades, FBOTs continue to be radiation powerhouses. Recently astronomers studied the Camel in wavelengths across the electromagnetic spectrum, getting a glimpse of some of the invisible carnage playing out after the initial blast.

The research team found that the initial Camel explosion also shone brightly in radio frequencies, suggesting that the blast was tearing through its cosmic neighbourhood extremely quickly, probably a few tenths of the speed of light.

Such bright radio emissions usually come from synchrotron radiation, which occurs when charged particles rocket through a magnetic field at a fraction of the speed of light. Behind the blast, a powerful engine seethed for months. Researchers found that the blast glowed with X-ray emissions long after its visible light faded. As with the Cow, this stream of X-rays suggests that something powerful – like a black hole or a neutron star – was driving the Camel's intense emissions.

It could be that FBOTs represent a rarely seen moment of cosmic creation, blasts that occur the instant an old star implodes, collapsing into a massive black hole or fast-spinning neutron star before our very eyes. Astronomers have never seen these processes actually take place – at least as far as they know – so it's hard to know for sure what the resulting flood of radiation would look like. But one thing is clear: the Cow, the Koala and the Camel are not your average mammals. There's nothing average about them.

PLANET EARTH

LIFE LOCKED INSIDE A RUBY

WORDS **YASEMIN SAPLAKOGLU**

Traces of ancient life have been found inside a 2.5-billion-year-old ruby from Greenland. The planet's oldest rubies, gemstones made up of a transparent red mineral called corundum, are found in Greenland. While searching for rubies in the North Atlantic Craton, researchers discovered a hidden surprise in one of them: graphite, a pure form of carbon, which may be the remains of ancient microbial life.

"The graphite inside this ruby is really unique," said Chris Yakymchuk, a professor at the University of Waterloo in Ontario. "It's the first time we've seen evidence of ancient life in ruby-bearing rocks." The team concluded the graphite came from an ancient life form after they analysed the ratio of different isotopes of carbon. More than 98 per cent of the carbon on Earth has a mass of 12 atomic mass units, but some carbon atoms are heavier, with a mass of 13 or 14 atomic mass units.

"Living matter preferentially consists of the lighter carbon atoms because they take less energy to incorporate into cells," Yakymchuk said. "Based on the increased amount of carbon-12, we concluded that the carbon atoms were once ancient life, most likely dead microorganisms such as cyanobacteria." At the time this bacteria likely lived, the planet didn't have much oxygen, an indispensable element for complex life, so the only life that could eke out an existence were teeny microbes and algae films. Cyanobacteria are thought to be some of the first life on Earth.

Scientists discovered hints of ancient life inside a 2.5-billion-year-old ruby

‘Hidden world’ discovered in Earth’s core

WORDS **JOANNA THOMPSON**

Earth’s ‘solid’ inner core might actually be a bit mushy. For over half a century, the scientific community thought that Earth’s inner core was a solid ball of compressed iron alloy surrounded by a liquid outer core. But recent research suggests that the firmness of the planetary ball ranges from hard to semi-soft to liquid metal. “The more we look at it, the more we realise it’s not one boring blob of iron,” said Jessica Irving, a seismologist at the University of Bristol. “We’re finding a whole new hidden world.”

In some ways, Earth’s inner core remains as mysterious as it was when Jules Verne published his fanciful *Journey to the Center of the Earth* in 1864. Though scientists have known since the 1950s that our planet isn’t hollow, as Verne predicted, the planet’s interior is still unexplored; the immense heat and pressure are too great for any human or human-made probe to travel there. “Unless something awful happens to our planet, we will never have a direct observation of Earth’s core,” Irving said.

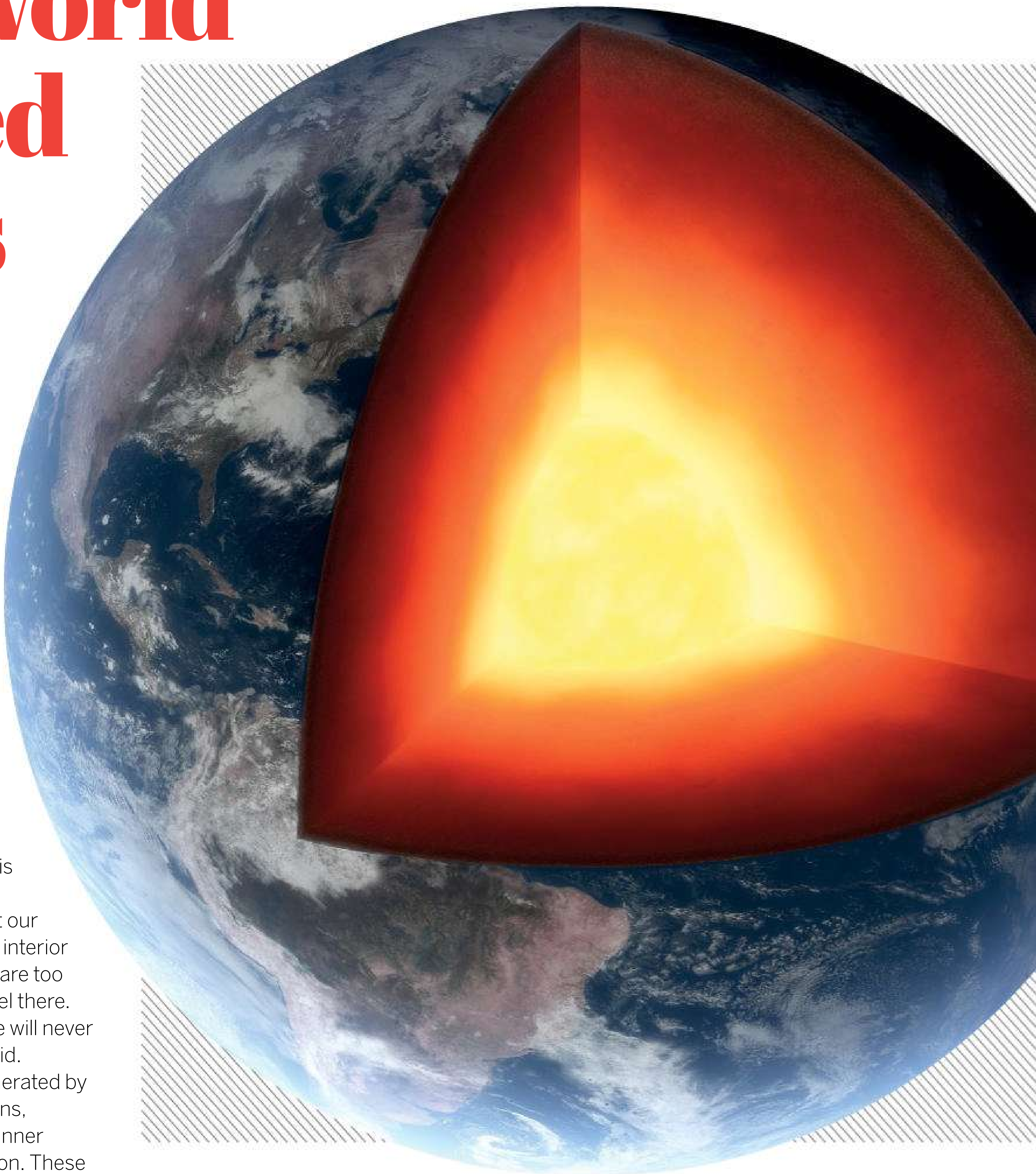
Instead, geophysicists rely on seismic waves generated by earthquakes. By measuring these massive vibrations, scientists can reconstruct a picture of the planet’s inner workings in a way that’s akin to a CT scan of a person. These waves come in two main flavours: straight-line compressional waves and undulating shear waves. Each wave can speed up, slow down or bounce off different mediums as it travels through the ground.

For Rhett Butler, a geophysicist at the Hawaii Institute of Geophysics and Planetology, the study started as a question of mismatched numbers. Butler was looking at how the seismic waves created by large earthquakes in five different locations travelled through Earth’s core to the exact opposite side of the globe. But something was off; the quakes’ shear waves, which should have passed through a solid ball of metal, were instead being deflected in certain areas.

The numbers surprised Butler. He knew the seismic wave maths was correct, which could mean only one thing... scientists had the structure wrong. “When you’re in this business, you’ve got to match the data,” he said. Researchers reevaluated their base assumption that Earth’s inner core was solid all the way through.

They discovered that the waves they observed worked if, rather than being a solid ball, the core had pockets of liquid and ‘mushy’, semi-solid iron near its surface.

The range of iron consistencies was particularly striking. “We’ve seen evidence that not only is it not soft everywhere, it’s really hard in some places,” Butler said. “It’s got hard surfaces right up against melted or mushy iron. We’re seeing a lot of detail within the inner core that we didn’t see before.” This could potentially revolutionise our understanding of Earth’s magnetic field. While the swirling liquid outer core drives our planet’s magnetic field, the inner core helps to modify the field. Other planets, like Mars, have a liquid centre but lack both an inner core and a magnetic field. Therefore, Butler and Irving believe, a deeper understanding of the inner core will help scientists understand the relationship between a planet’s interior and its magnetic activity.



Earth’s inner core is made primarily of hot, compressed iron

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Christmas reading list

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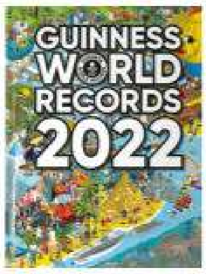
AUTHOR: **GUINNESS WORLD RECORDS**

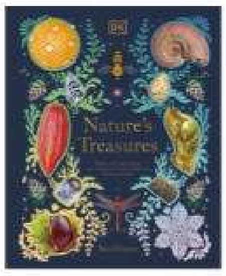


Discover a unique mix of remarkable humans, talented pets, incredible vehicles, impressive sporting legends and the latest cutting-edge science. Despite the challenges of 2021, the team at Guinness World Records has yet again compiled the latest achievements of record breakers from around the world. Inside you'll find chapters including environmental champions, sporting heroes, the tallest and shortest and more.

NATURE'S TREASURES

£20 / $24.99

AUTHOR: **BEN HOARE**

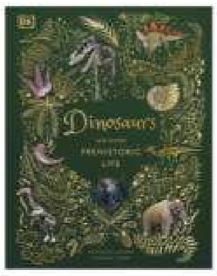


Dive into this collection of more than 100 intriguing items from the natural world and discover the stories behind them. Written by award-winning journalist Ben Hoare, examine a whale's bristly teeth and learn how they eat tiny animals, see why butterflies shine and glitter in the sunlight with their miniature wing scales and discover what makes every snowflake unique by admiring their tiny, branching crystals of ice.

DINOSAURS AND OTHER PREHISTORIC LIFE

£20 / $24.99

AUTHOR: **ANUSUYA CHINSAMY-TURAN**



This is a wonderful gift for any dinosaur fan – perfect for children to explore by themselves or to read with an adult at bedtime. From Tyrannosaurus and sabre-toothed cats to ferns and woolly mammoths, every page will captivate young readers. Go on a time-travelling adventure and marvel at the plants and animals from the Earth's primaeval past in this stunning book about dinosaurs and prehistoric life.

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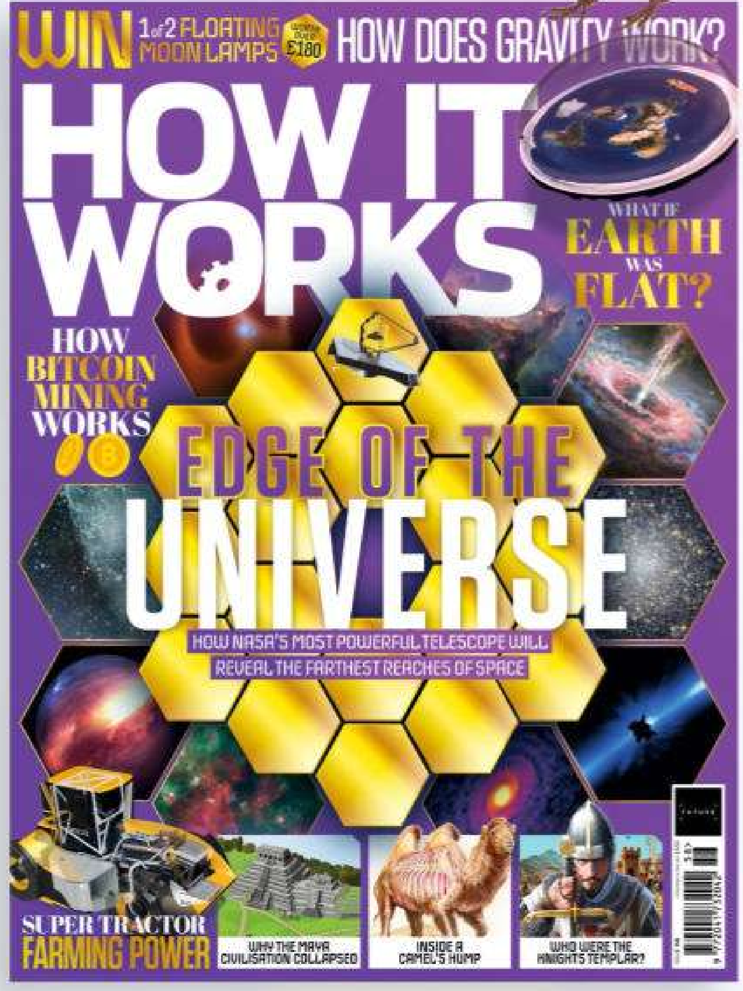
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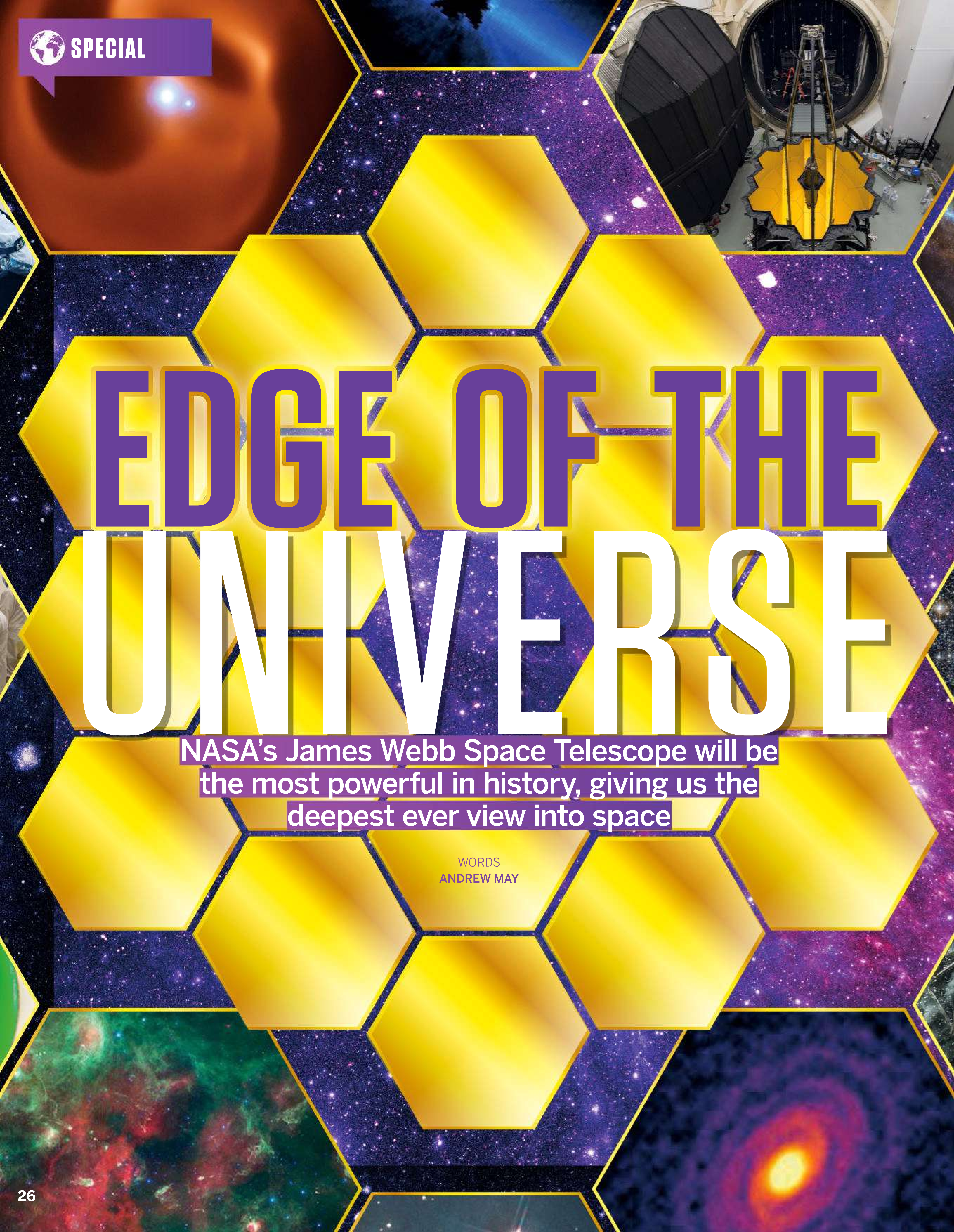


EDGE OF THE UNIVERSE

NASA's James Webb Space Telescope will be the most powerful in history, giving us the deepest ever view into space

WORDS
ANDREW MAY

DID YOU KNOW? Around 48 grams of gold are used in the Webb mirror, comparable to the mass of a golf ball

The Hubble Space Telescope is a hard act to follow. In the three decades since it was launched in 1990, it's revealed the wonders of the universe in unprecedented detail. It's been used to study cutting-edge topics like dark energy and exoplanets that were scarcely dreamed of when it began operation. It's also captured the public's imagination to the extent that it's now a household name. That's the kind of reputation Hubble's successor will have to live up to.

That successor is called the James Webb Space Telescope (JWST), or Webb for short. Like Hubble, it will be operated primarily by NASA, which is providing the bulk of the funding, with the European Space Agency (ESA) as a junior partner. The telescope is named after one of NASA's early administrators, James E. Webb, who oversaw the creation of the Apollo program in the 1960s. It was way back in 2002 – almost 20 years ago – that Webb's name was first applied to what had previously been referred to as the Next Generation Space Telescope. This was originally planned to cost half a billion dollars and be ready for launch in 2007. But these estimates turned out to be hopelessly over-optimistic, given the enormously complex and innovative design of the spacecraft. By the time it's finally launched, hopefully before the end of 2021, it will have cost almost £10 billion (£7.3 billion).

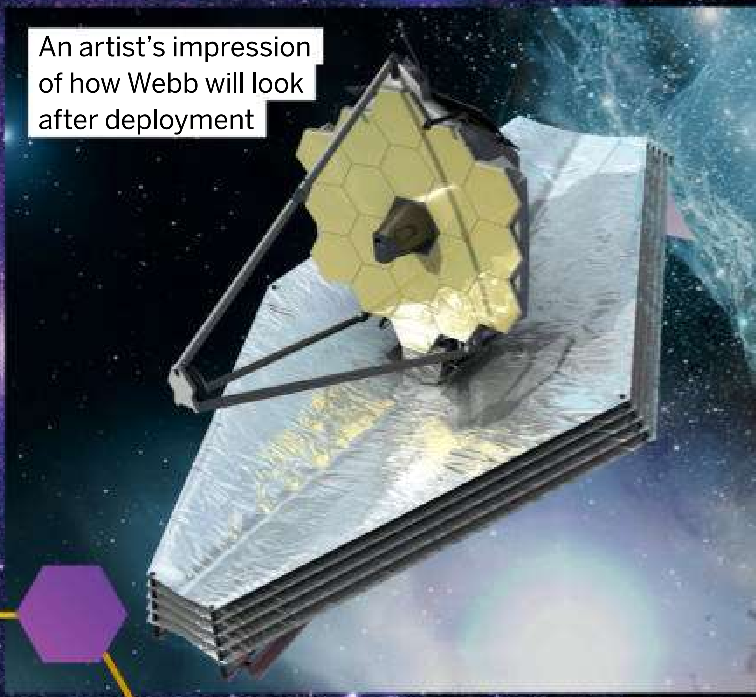
Nevertheless, the scientists involved in the project believe the results will more than compensate for the time and money invested in it. NASA is keen to emphasise that Webb isn't simply a bigger and more powerful replacement for Hubble. It's both of those things, of course – with more than two-and-a-half times the diameter and a hundred times the sensitivity – but at heart it's a different type of instrument altogether. Ordinary optical telescopes see in the same part of the spectrum as our eyes, covering a range of wavelengths between roughly 380 and 740 nanometres (nm). Hubble spanned all of this, plus a little way into the ultraviolet at shorter wavelengths and infrared at longer ones. But the JWST will primarily be an infrared telescope, optimised for 600 to 28,000 nanometres. It won't be able to see green or blue light, just orange and red, plus a wide range of longer wavelengths beyond that.

For many astronomical objects, these very long wavelengths are more useful to astronomers than the visible spectrum. But infrared poses problems for Earth-based observers, because much of it is blocked by our planet's atmosphere. On top of that, planet Earth produces its own infrared emissions via heat radiation, which tend to swamp the fainter astronomical sources. So the best place for an infrared telescope is out in space, as far as possible from the Earth and all its unwanted sources of heat.

Following in the footsteps of the ESA's Herschel infrared observatory, Webb will be located around 932,000 miles from Earth at Lagrange point L2. This will give it a much clearer view of the universe than the one Hubble has in low-Earth orbit, but it does have a downside. Unlike its predecessor, it won't be a relatively simple matter to send astronauts up to repair it if it breaks down. Everything has to work perfectly on the first attempt, which is one of the reasons it's taken NASA the best part of two decades to get it ready for launch.

Did you know?
Webb is the largest telescope ever placed in space

© Getty / ESA



An artist's impression of how Webb will look after deployment

How WEBB works

The telescope has some unique design features, like a segmented mirror and a huge sunshield

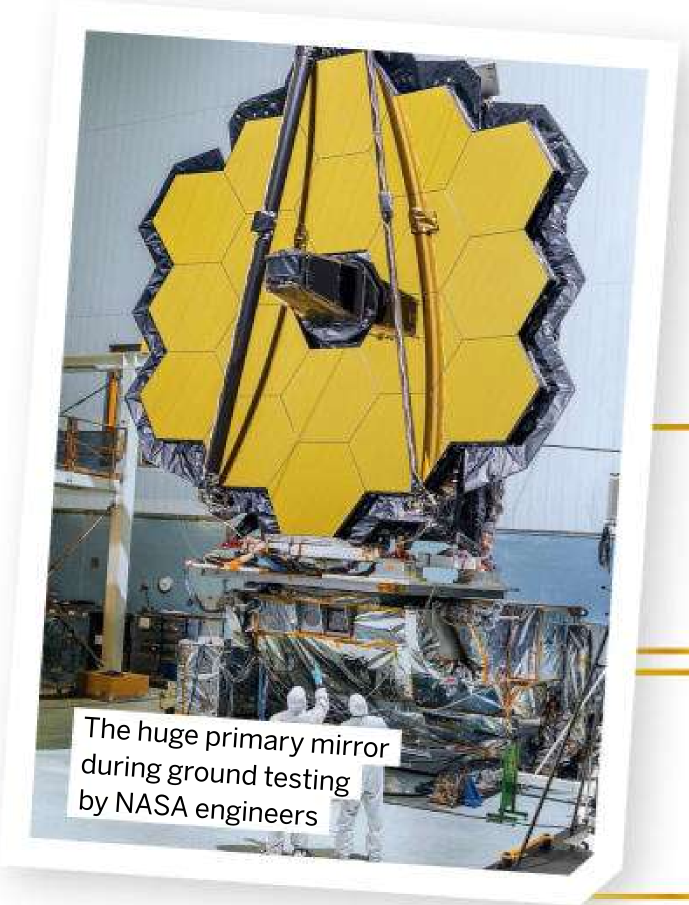
AR zone SCAN HERE

Externally, Webb looks very different from Hubble. The latter, just like a traditional telescope, is enclosed in a cylindrical tube that shields the optics from stray light. Depending on its position in its orbit, Hubble can be exposed to a lot of this – blazing sunshine from one direction, reflections from Earth's surface in another and maybe even the Moon. But Webb is more fortunate. Seen from the L2 point, all these sources are in more or less the same direction, so all the telescope needs is a single large sunshield. The bare optics, in the form of primary and secondary mirrors, sit on top of this. The result, at first glance, looks more like a radio telescope than an optical one.

Functionally, however, both Webb and Hubble are constructed on the same principles. They're both built around a large primary mirror, which has the crucial job of capturing as much light as possible from objects that may be on the very edge of the observable universe. In essence, the bigger this mirror is, the better. In Hubble's case the mirror is 2.4 metres in diameter, made from a single circular piece of glass. If this was scaled up to the size needed for the JWST – around 6.5 metres across – then not only would it be extremely difficult to fabricate, but the result would be too large and heavy to launch into space.

Instead, Webb's mirror is constructed from 18 hexagonal segments; these can fold up for launch and then deploy into an operational configuration once in space. Although NASA considered making the segments from glass, like Hubble's mirror, in the end they used beryllium, a very strong, lightweight metal commonly employed in high-speed aircraft and space vehicles. This needs to be shaped and polished to extremely high accuracy in order to produce images with the necessary clarity – NASA estimates the polishing error to be less than a millionth of an inch. After achieving the desired shape, the mirror segments were then coated with a thin layer of pure gold to maximise reflectivity at infrared wavelengths.

When all the segments are put together, they achieve the desired 6.5-metre diameter for the main mirror. That's around 2.7 times as big as Hubble's, but the actual performance improvement is much greater than this. That's because the light-collecting power of a mirror is proportional to its area rather than its diameter. Allowing for the hexagonal shape of the segments and the hole in the centre, the effective area of Webb's mirror is 25 square metres, compared with four square metres for Hubble. That equates to a performance improvement better than a factor of six.

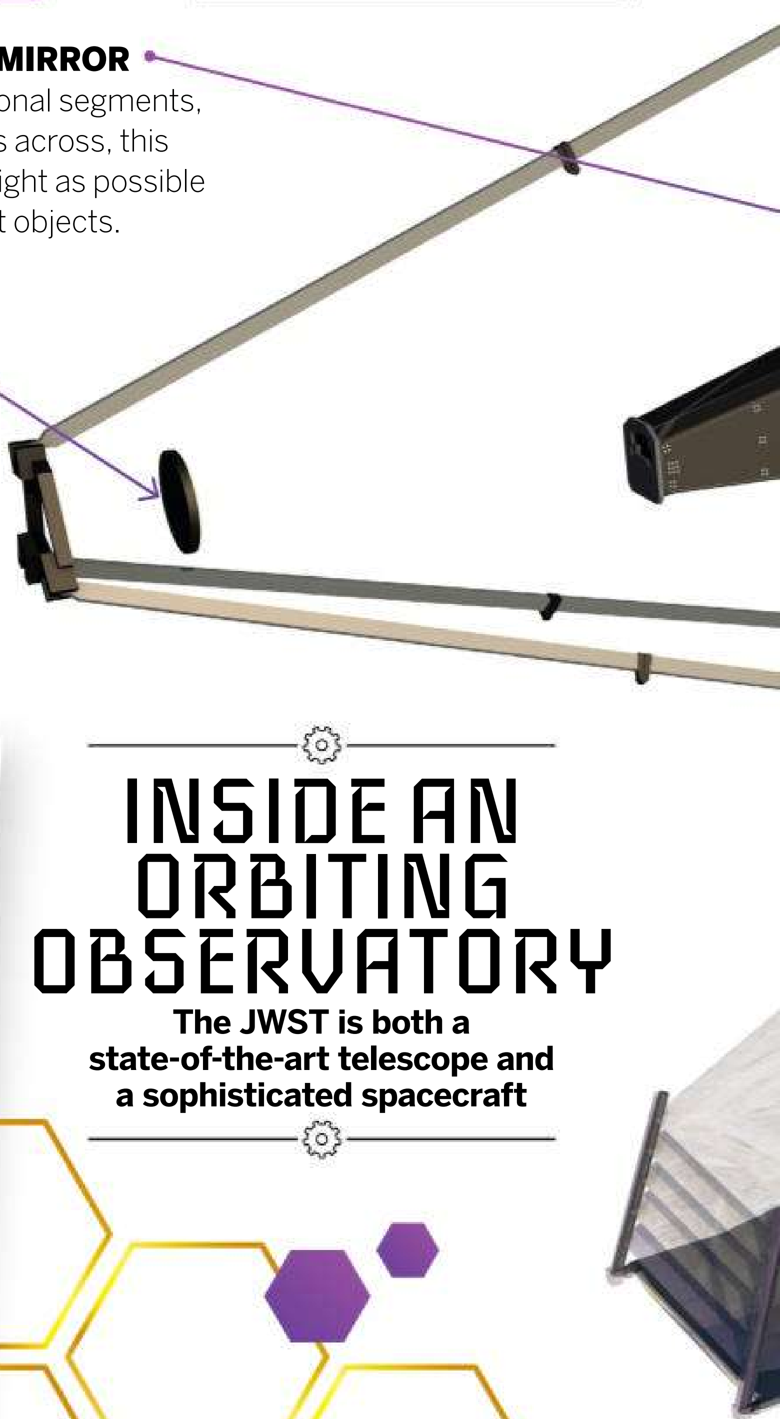


The huge primary mirror during ground testing by NASA engineers

Did you know?
Webb weighs as much as a full-size school bus

INSIDE AN ORBITING OBSERVATORY

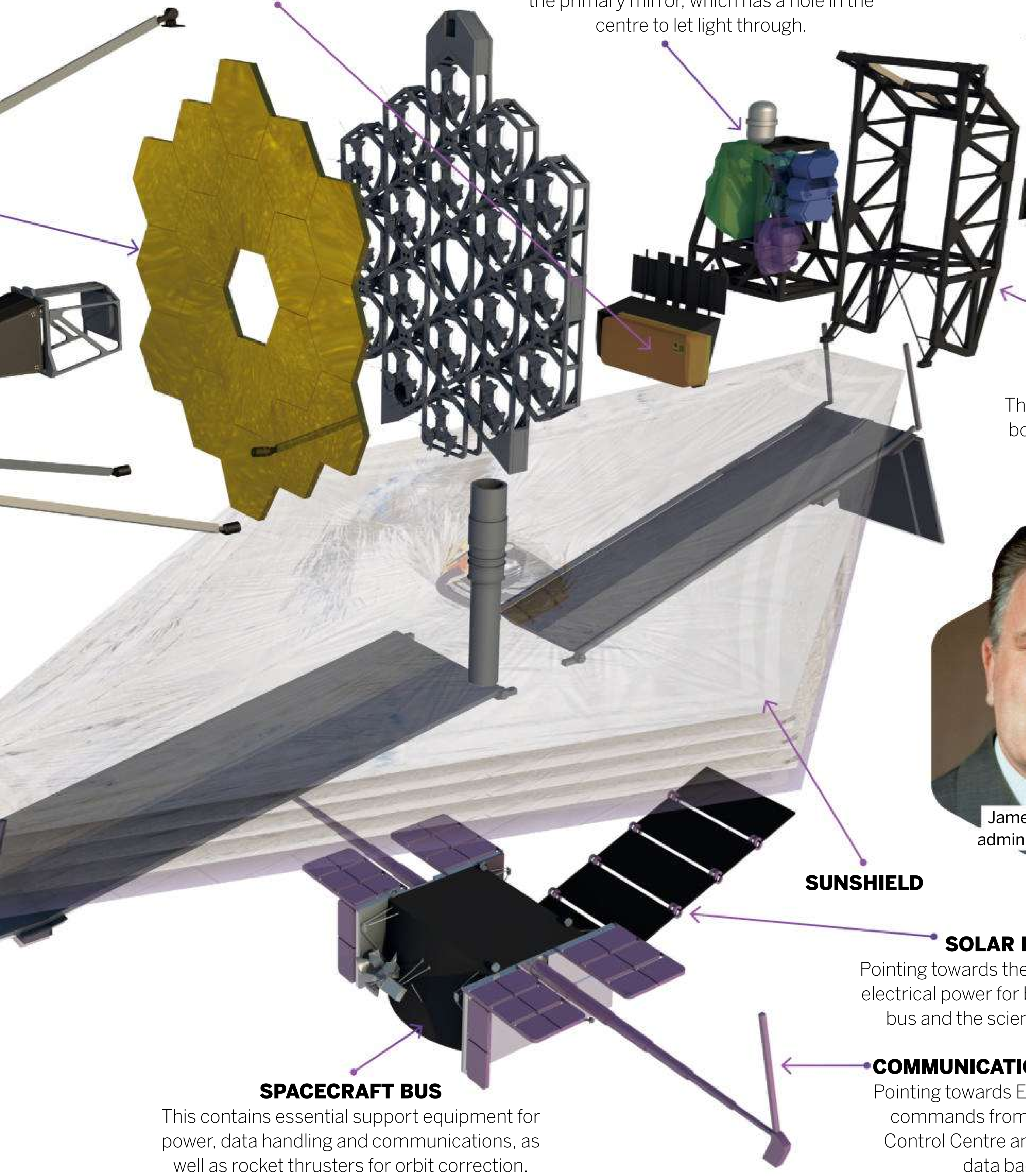
The JWST is both a state-of-the-art telescope and a sophisticated spacecraft



PRIMARY MIRROR
Made of 18 hexagonal segments, each 1.3 metres across, this collects as much light as possible from distant objects.

SECONDARY MIRROR
74 centimetres in diameter, this reflects the focused image from the main mirror back to the science instruments.

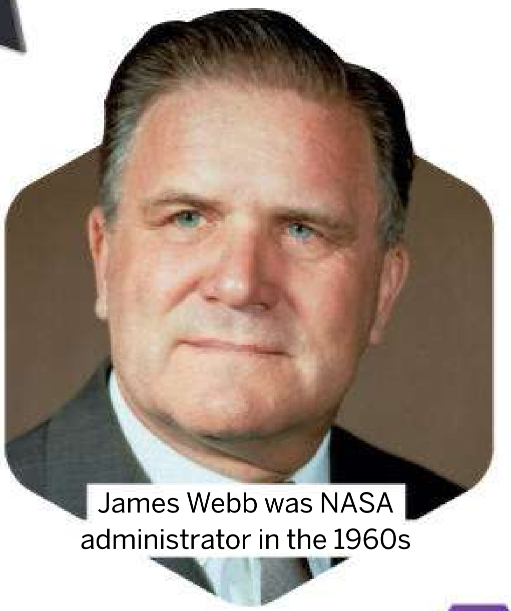
DID YOU KNOW? James Webb was a politically controversial figure, and some astronomers are unhappy about using his name



ISIM ELECTRONICS COMPARTMENT

INTEGRATED SCIENCE INSTRUMENT MODULE (ISIM)
The science instruments are located behind the primary mirror, which has a hole in the centre to let light through.

BACKPLANE
This sturdy structure has to carry both the telescope's mirrors and its science instruments – 2,400 kilograms in total.



James Webb was NASA administrator in the 1960s

SUNSHIELD

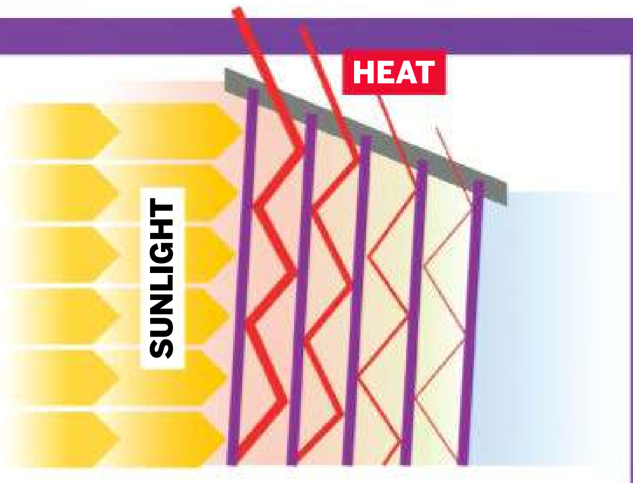
SOLAR PANELS
Pointing towards the Sun, these provide electrical power for both the spacecraft bus and the science instruments.

COMMUNICATIONS ANTENNA
Pointing towards Earth, this receives commands from the Operations Control Centre and sends science data back to it.

SPACECRAFT BUS
This contains essential support equipment for power, data handling and communications, as well as rocket thrusters for orbit correction.

SUNSHIELD

Located at the L2 point, the JWST will sit in constant bright sunshine. This is healthy for the equipment in the spacecraft bus, but bad news for the optical instruments and science module. Because they observe in the infrared, they need to be kept as cold as possible in order to function correctly. The two halves of the spacecraft will be separated by a huge, kite-shaped, five-layer sunshield, 21 metres long by 14 wide, which is roughly the size of a tennis court. While the sunlit side may reach temperatures of 100 degrees Celsius, the cold side will be as low as -237 – just 36 degrees above absolute zero.



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Launch and DEPLOYMENT

There's a perfect spot in space for an infrared telescope, and Webb is heading there

A key feature of Webb's design is that it has a 'cold side' and a 'hot side'. The cold side is the one that does the observing, while the hot side carries the spacecraft's solar panels and an antenna for two-way communication with Earth. But this arrangement only works if the Sun and Earth are always in the same direction from the spacecraft's point of view.

This wouldn't be the case if it was simply placed in Earth orbit like Hubble, nor would it be true if the spacecraft orbited the Sun at a slightly different distance from Earth's orbit. But it turns out there is one special distance at which an object can orbit the Sun and always see the Sun and Earth in the same direction. This is the so-called L2 point, and it's where the James Webb Space Telescope will operate.

L2 is one of several locations called Lagrange points, after Joseph-Louis Lagrange, who studied them in the 18th century. At these locations, the gravity of two massive bodies – in this case the Sun and Earth – conspire to keep a third, smaller body, such as an asteroid or spacecraft, in a fixed position relative to the first two.

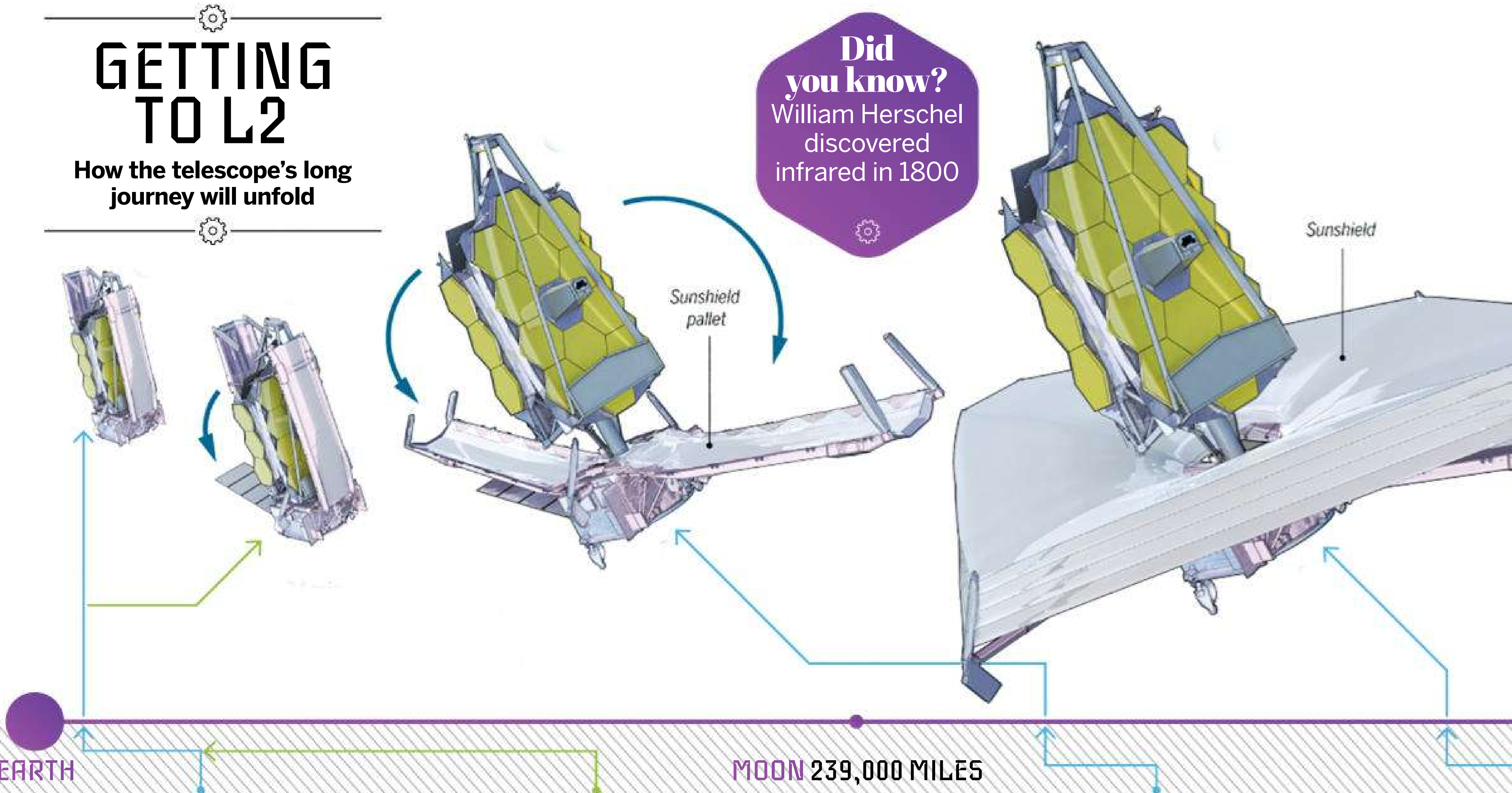
These Lagrange points aren't stationary, but they revolve around the Sun at exactly the same rate as Earth, so their distance from us always stays the same. In the case of L2, it's around 930,000 miles away – around four times as far away as the Moon.

To get the telescope all the way out to L2 requires a powerful launch vehicle, which will be the European Space Agency's Ariane 5 rocket. In just 26 minutes following liftoff from French Guiana, this will carry Webb free of Earth's atmosphere and put it on course for L2. The spacecraft will then separate from the rocket and cruise for around a month before finally arriving at its destination.

GETTING TO L2

How the telescope's long journey will unfold

Did you know?
William Herschel discovered infrared in 1800



30 MINUTES

SPACECRAFT SEPARATION

The Ariane 5 launch vehicle will accelerate Webb to faster than the Earth's escape velocity so it can travel straight to L2 without entering orbit. After this, they separate.

34 MINUTES

SOLAR PANELS DEPLOY

A number of key systems locked during launch will be released, including the all-important solar panels that provide the spacecraft with its electrical power.

THREE DAYS

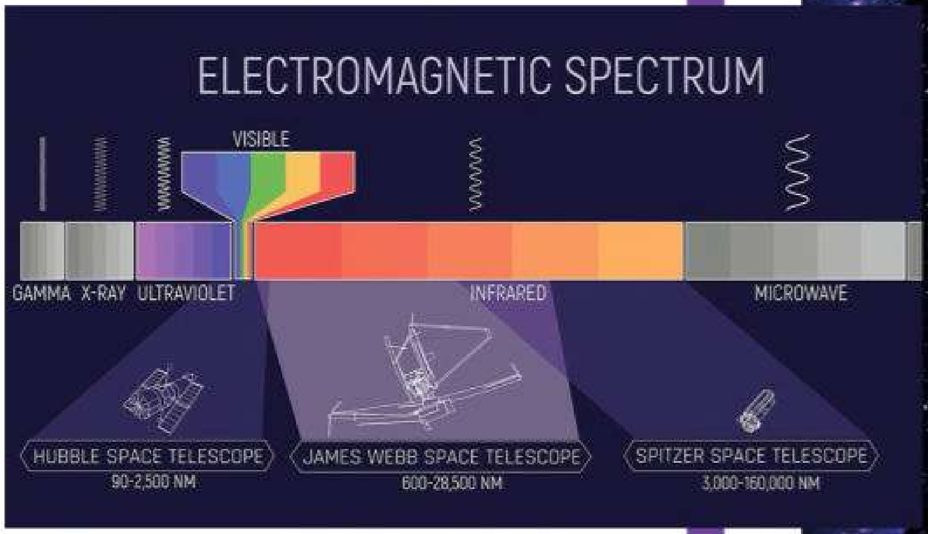
SUNSHIELD PALLETS DEPLOY

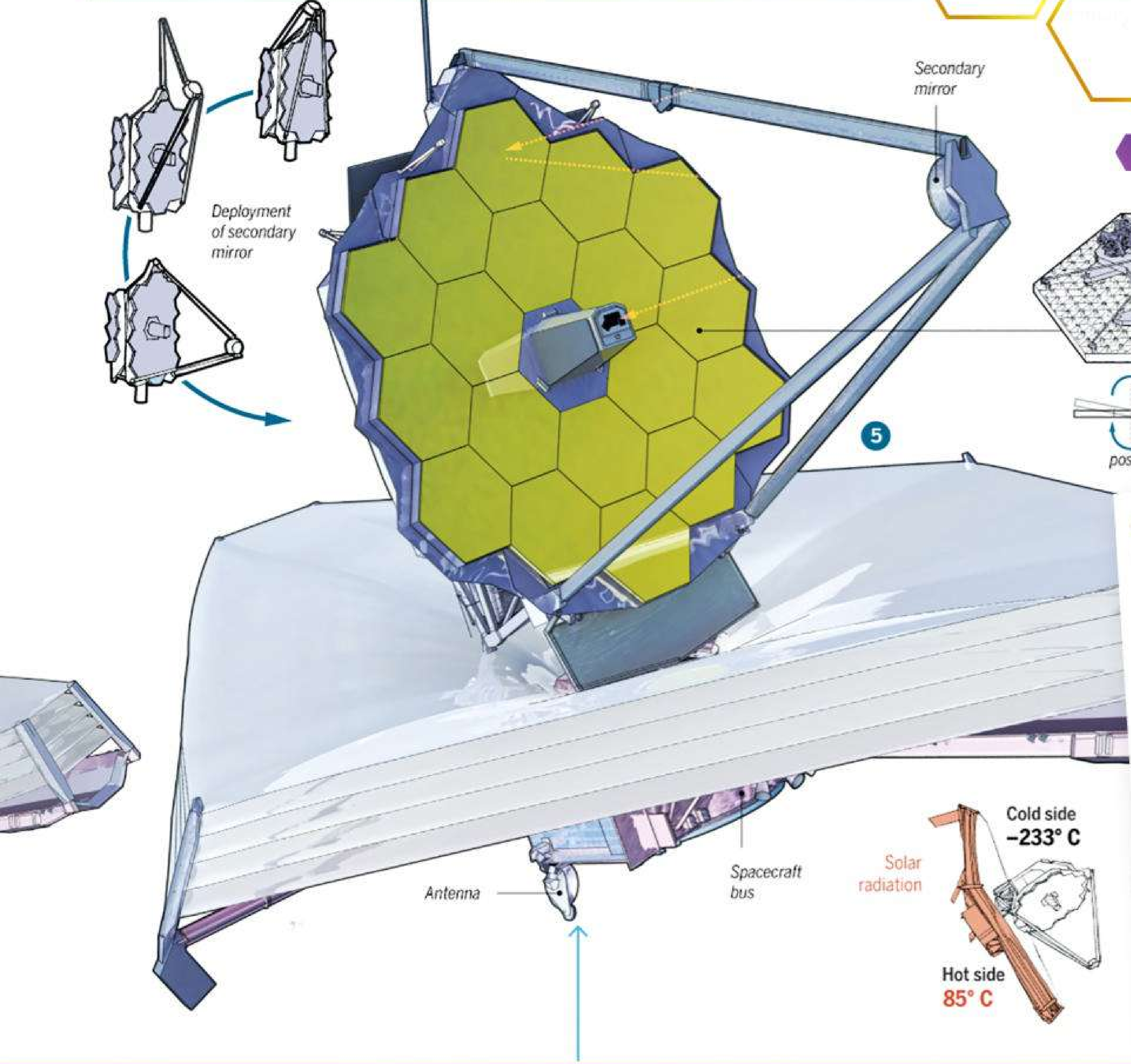
After a couple of trajectory corrections, the main deployment will start halfway through the first week. The first major step is to unfold the pallets holding the sunshield.

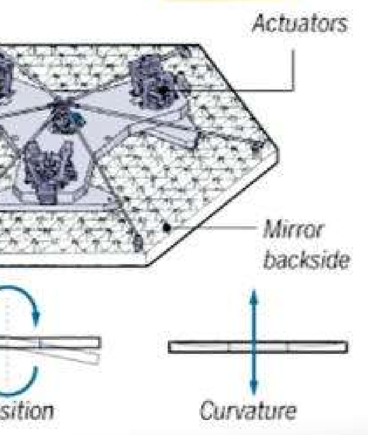
DID YOU KNOW? Other spacecraft to occupy the L2 point have included the ESA's Planck, Herschel and Gaia telescopes

WHY INFRARED?

We normally think of astronomy in terms of visible light, because that's what our eyes and traditional telescopes see. But astronomical objects produce emissions across the whole of the electromagnetic spectrum, from long-wavelength radio waves to short-wavelength X-rays and gamma rays. Our eyes evolved to see the wavelengths they do because that's where the Sun emits most of its energy, but cooler objects – such as planets and newly formed stars – tend to radiate at longer wavelengths than this. This is one reason why infrared telescopes such as Webb – and its predecessor, NASA's Spitzer Space Telescope, which operated between 2003 and 2020 – are so important. A second reason is that while the dust in galaxies absorbs visible light, it's virtually transparent to infrared waves. This means even Sun-like stars can be easier to see in the infrared if there's a lot of intervening dust.


ELECTROMAGNETIC SPECTRUM
VISIBLE
GAMMA
X-RAY
ULTRAVIOLET
INFRARED
MICROWAVE
HUBBLE SPACE TELESCOPE 90-2,500 NM
JAMES WEBB SPACE TELESCOPE 600-28,500 NM
SPITZER SPACE TELESCOPE 3,000-160,000 NM


Deployment of secondary mirror
Secondary mirror
5
Antenna
Spacecraft bus
Solar radiation
Cold side
−233° C
Hot side
85° C


Actuators
Mirror backside
position
Curvature

The telescope in its fully folded configuration, prior to installation on the launch vehicle

FINAL ORBIT 932,000 MILES

SIX DAYS

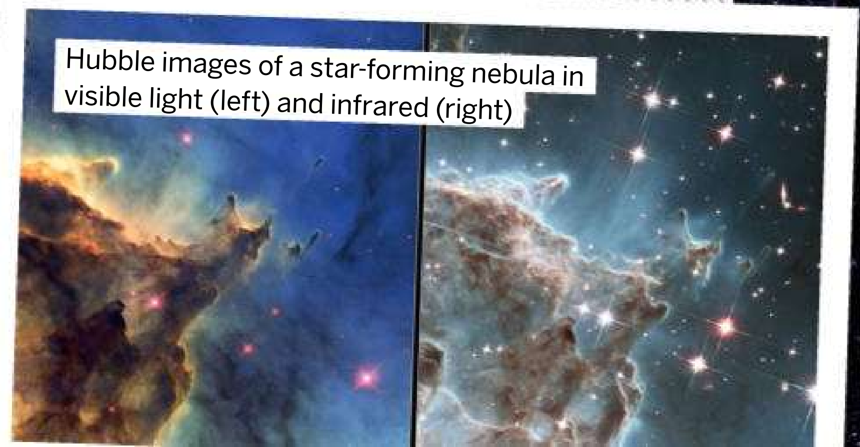
SUNSHIELD EXTENDED

The spacecraft bus and the optical assembly will move two metres farther apart, allowing room for the sunshield to deploy fully in the space between them.

TWO WEEKS

FINAL CONFIGURATION

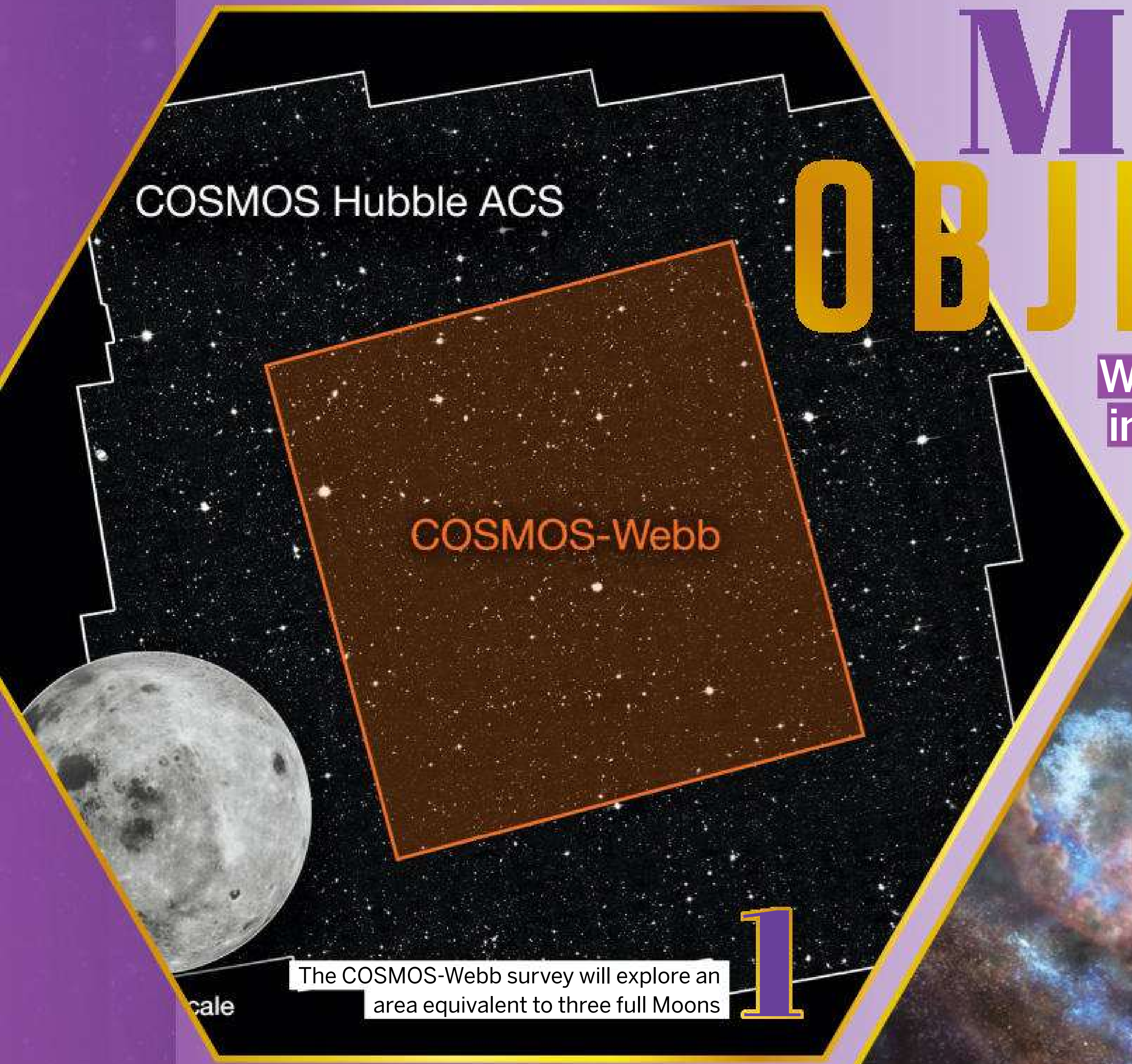
The spacecraft will be fully deployed, with the primary and secondary mirrors locked in place. As it completes its journey to L2, initial testing of software and electronics can begin.


Hubble images of a star-forming nebula in visible light (left) and infrared (right)

©NASA/JPL/ESA

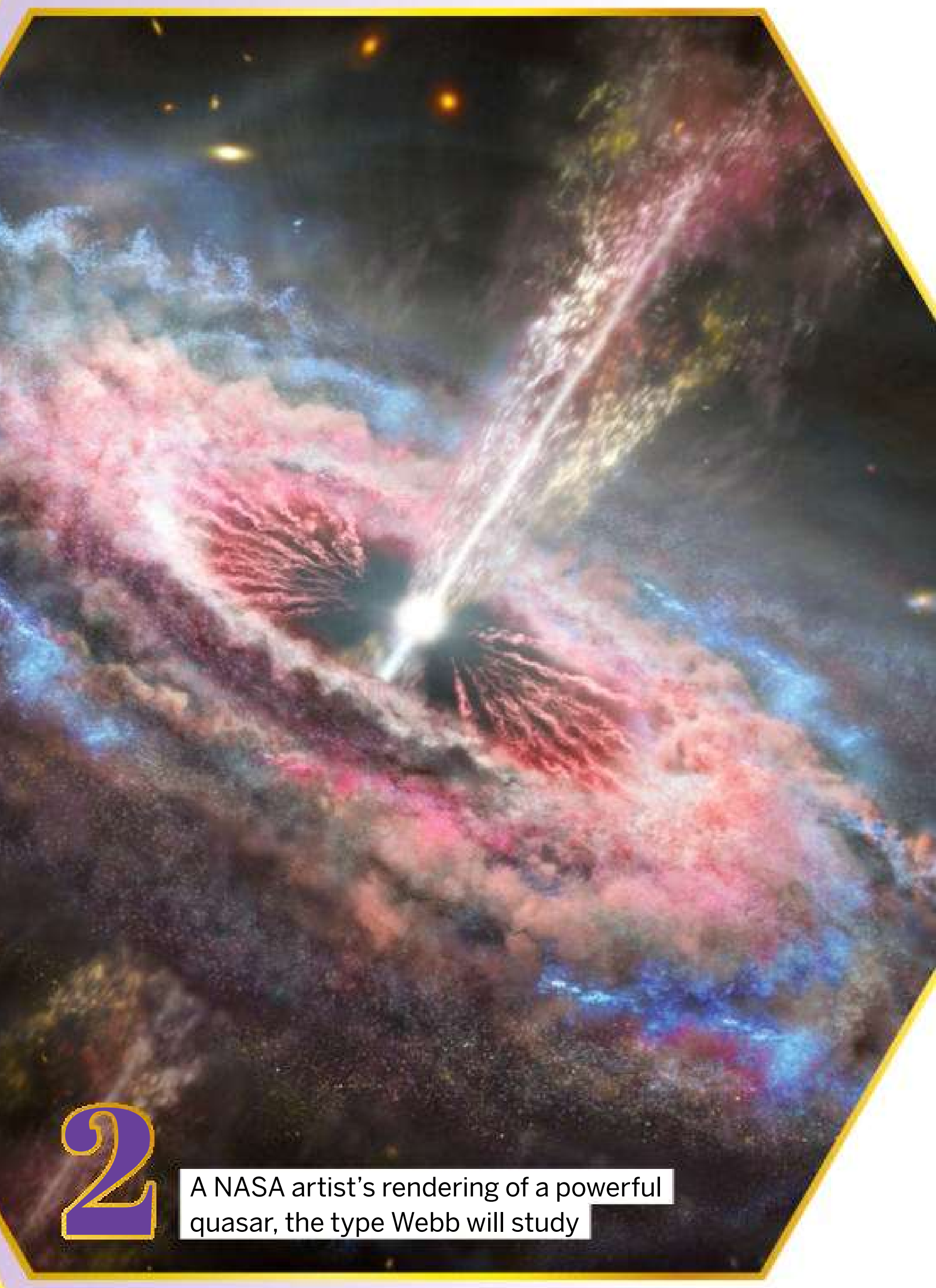
Mission OBJECTIVES

Webb's science goals are organised into four themes, addressing some of astronomy's biggest questions



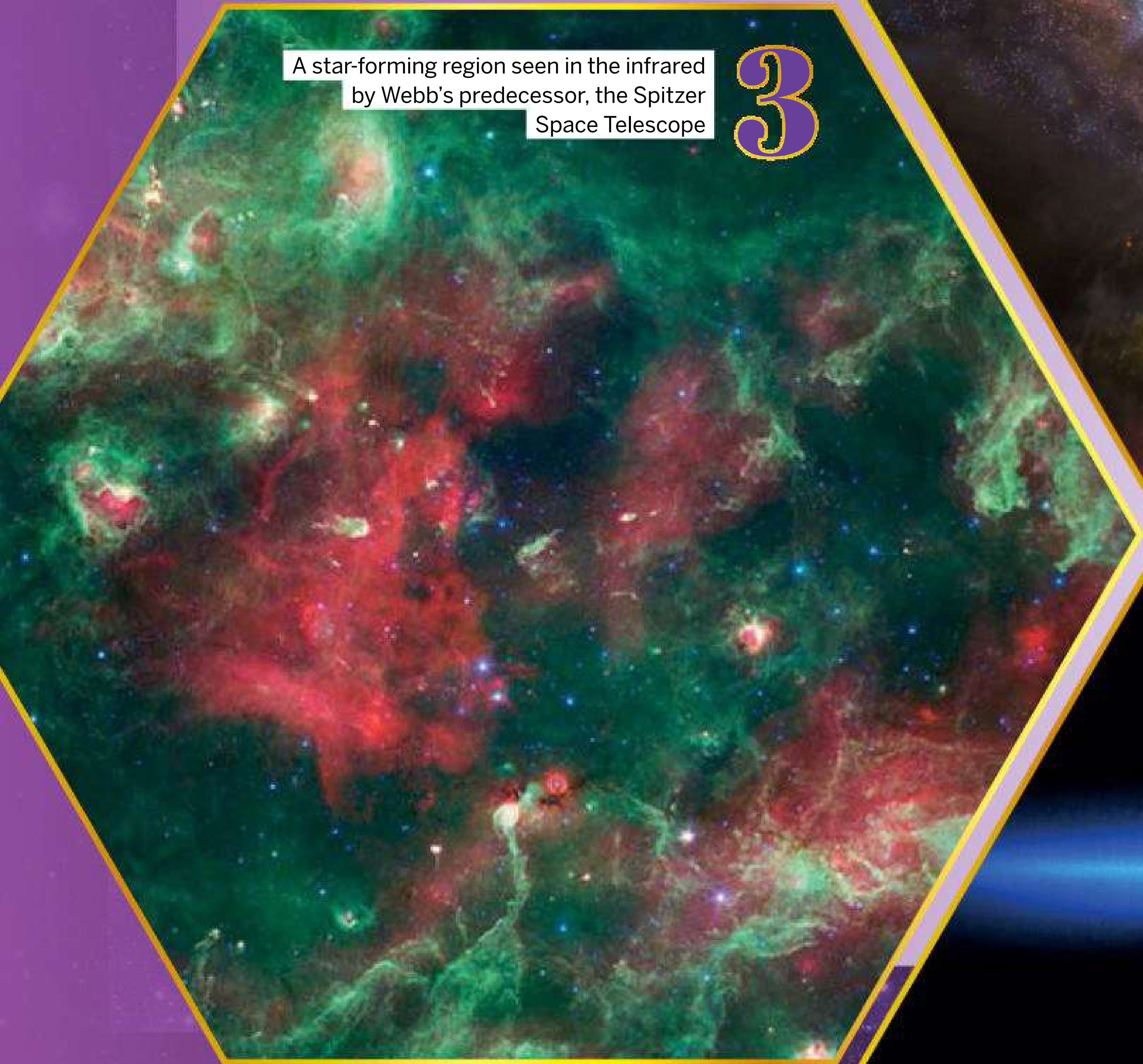
1

The COSMOS-Webb survey will explore an area equivalent to three full Moons



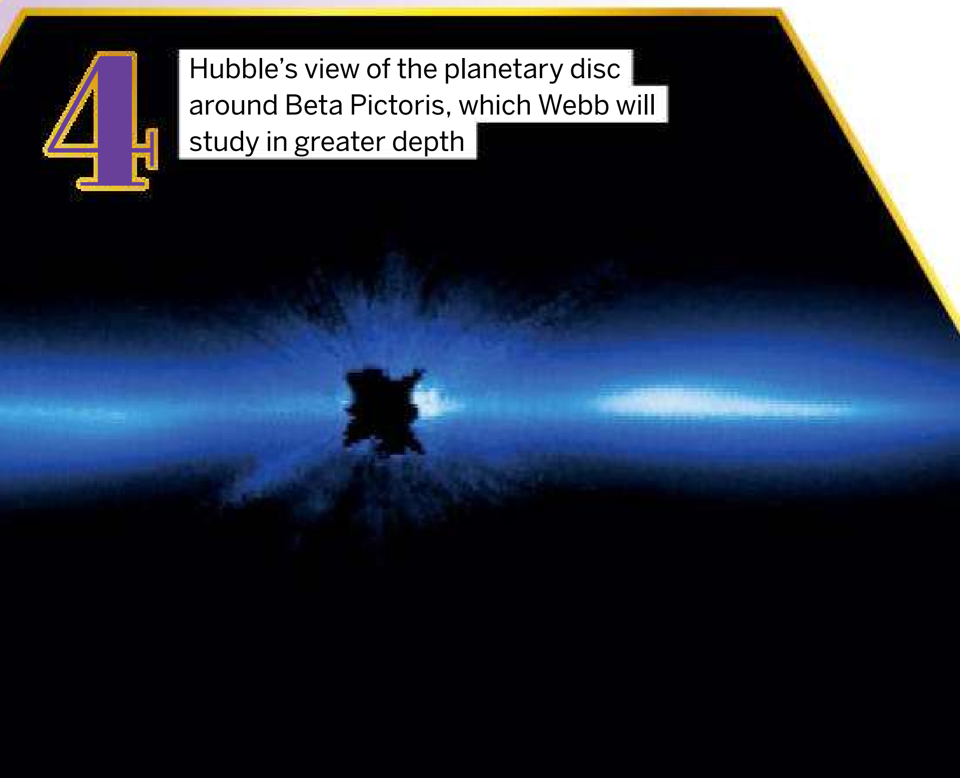
2

A NASA artist's rendering of a powerful quasar, the type Webb will study



3

A star-forming region seen in the infrared by Webb's predecessor, the Spitzer Space Telescope



4

Hubble's view of the planetary disc around Beta Pictoris, which Webb will study in greater depth

DID YOU KNOW? One of the JWST's first science tasks, the COSMOS-Webb survey, will encompass half a million galaxies

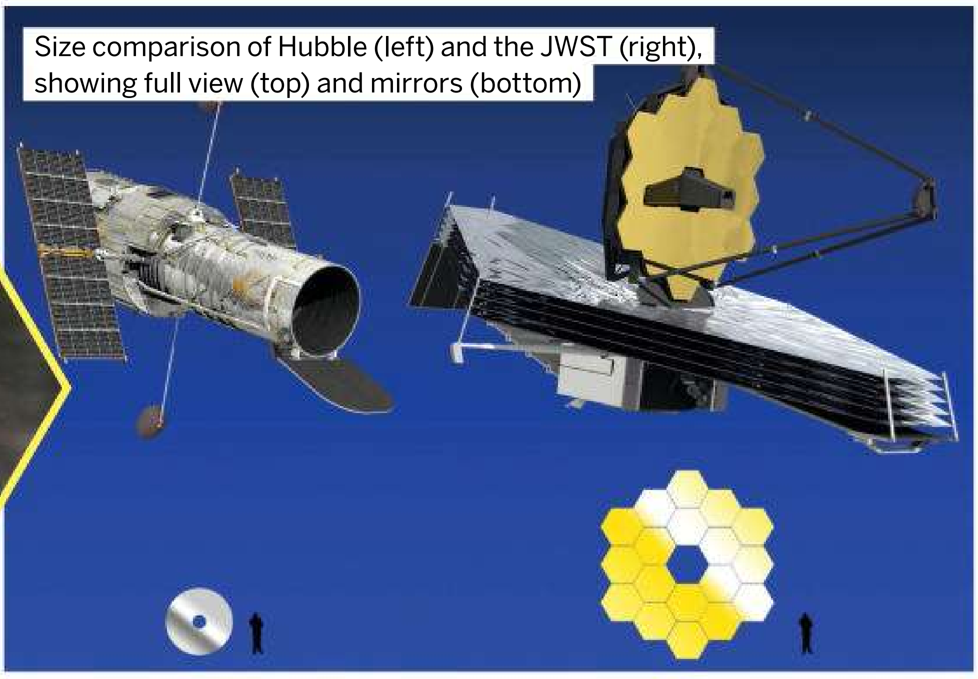
1 THE EARLY UNIVERSE

Because light from distant objects travels at a finite speed, we see things as they used to be in the past. Hubble has shown us galaxies as they were many billions of years ago, but the JWST will be even more sensitive. NASA hopes it will see all the way back to when the first galaxies formed, around 13.6 billion years ago. Because the universe is expanding, light from distant objects is stretched out, increasing its wavelength. This means light emitted in the visible waveband actually reaches us in the infrared.

Did you know?
The JWST's biggest aim is to probe our cosmic origins

2 GALAXIES OVER TIME

Thanks to Hubble, we know what galaxies look like – collections of stars, often arranged in elegantly symmetric spiral patterns. But these tend to be relatively nearby galaxies, and hence mature ones. The glimpses that Hubble has provided of very early galaxies suggests they are smaller and scrappier. No one knows how galaxies formed or how they clumped together to produce the larger, regular-looking galaxies we see today. It's hoped that Webb will be able to answer questions like these with its ultra-deep view of the early universe.


Size comparison of Hubble (left) and the JWST (right), showing full view (top) and mirrors (bottom)

3 LIFE CYCLE OF STARS

Stars are born, develop, age and die, and the remnants of old stars contribute to the raw material needed to make new stars. Much of this process is well understood, but there's still a mystery surrounding the actual birth of stars, and the planetary discs that may form around them. That's because these are initially enveloped inside a cocoon of dust, which ordinary telescopes using visible light can't penetrate. But all of this dust will be virtually transparent at the infrared wavelengths used by Webb, so NASA hopes it will finally reveal the ultimate secrets of star formation.

4 OTHER WORLDS

One of the most exciting areas of astronomy is the search for exoplanets, particularly Earth-like planets that may have conditions for life to evolve. The JWST will use infrared imaging and spectroscopy to study the chemical and physical properties of planetary systems. Its ability to peer through dust and snap high-resolution images should provide us with a direct view of planetary systems in their very earliest stages. Webb will also analyse the chemical composition of exoplanet atmospheres, looking in particular for telltale signatures of the building blocks of life.

JWST SCIENCE Q&A

We ask NASA's Dr Mike McElwain about his hopes for the new telescope

What sort of science will the telescope do in its first year?

In the first year, Webb's observing program will run the cosmic gamut from the first light in the early universe to exoplanet atmospheres. Webb will observe the most interesting objects in the universe with a combination of improved resolution, sensitivity and wavelength coverage. This will enable new and enhanced characterisation of the famous objects in the sky. If you can name it, Webb is likely to observe it, though maybe not all in the first year.

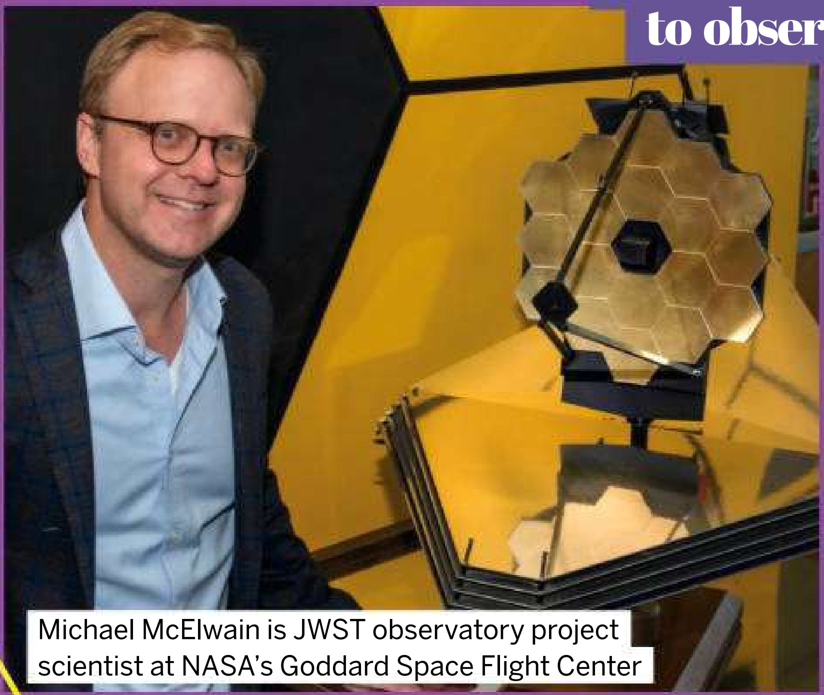
What are the most exciting discoveries the JWST might make?

When you have an observatory as transformational as Webb, the most exciting discoveries are likely to be the ones that we don't even anticipate. Webb's infrared eyes on the universe will enable us to see space where we were previously blind. Its unprecedented infrared sensitivity will help astronomers compare the earliest galaxies to today's grand spirals and ellipticals, helping us to understand how galaxies assemble over billions of years. It will be able to see right through and into massive clouds of dust that are opaque to visible-light observatories like Hubble, where stars and planetary systems are being born. Webb will tell us more about the atmospheres of extrasolar planets, and perhaps even find the building blocks of life elsewhere in the universe.

Do you think that Webb will become a household name like Hubble?

I fully expect it will, and that people around the globe will be discussing Webb imagery while sitting around the dinner table. Similar to Hubble, Webb will produce spectacular images of the cosmos that will captivate the imagination. We expect Webb imagery to go viral on the internet, show up in calendars and occupy space on household coffee tables.

> "If you can name it, Webb is likely to observe it"


Michael McElwain is JWST observatory project scientist at NASA's Goddard Space Flight Center

©NASA / ESA / Alamy / NASA/Jolearra Tshiteya

JWST by numbers

Although operated by NASA, the JWST was built by Northrop Grumman

1 MILLION

Webb's sunshield has a Sun-protection factor 50,000 times higher than high-SPF suncream

0.001

Webb's gold coating is 1,000 times thinner than the width of a human hair

4

Number of infrared space telescopes prior to the JWST

5 YEARS

Webb has a reasonably long minimum design life

6,500 KG

Total mass of the spacecraft – around the same as four family cars

4,843

Confirmed exoplanets as of October 2021

TWO KILOWATTS

The electrical power generated by the solar panels is enough to power a small home

ALL THE DATA FROM WEBB WILL BE PUBLICLY AVAILABLE ONLINE

1,000

Hundreds of people were involved in designing and building the JWST

DID YOU KNOW? Webb has a third mirror, in addition to the primary and secondary ones, to correct for astigmatism

WEBB COULD DETECT HEAT FROM A BUMBLEBEE ON THE MOON

125 BILLION

The estimated number of galaxies in the observable universe

6 MONTHS

It will be half a year from launch to the first full-quality images

L2 ORBITS THE SUN ONCE PER YEAR, JUST LIKE EARTH

$837 MILLION

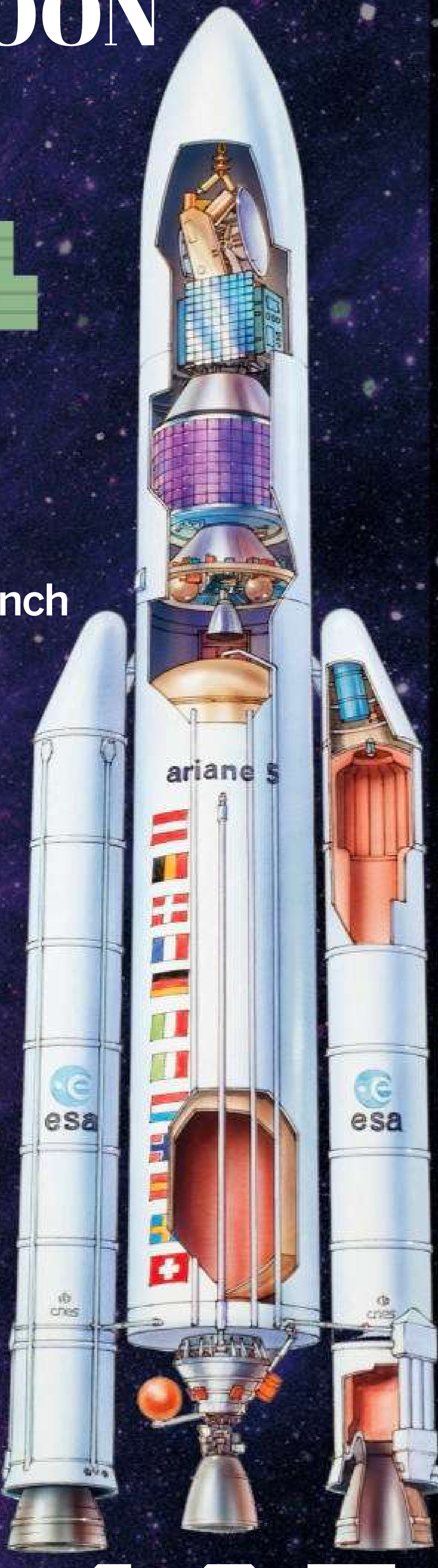
The JWST's total post-launch operations budget

39%

Webb can view nearly half the sky at any time

57.2 GIGABYTES

A huge amount of data can be downloaded each day



100 MILLION YEARS

The earliest time after the Big Bang that Webb will see

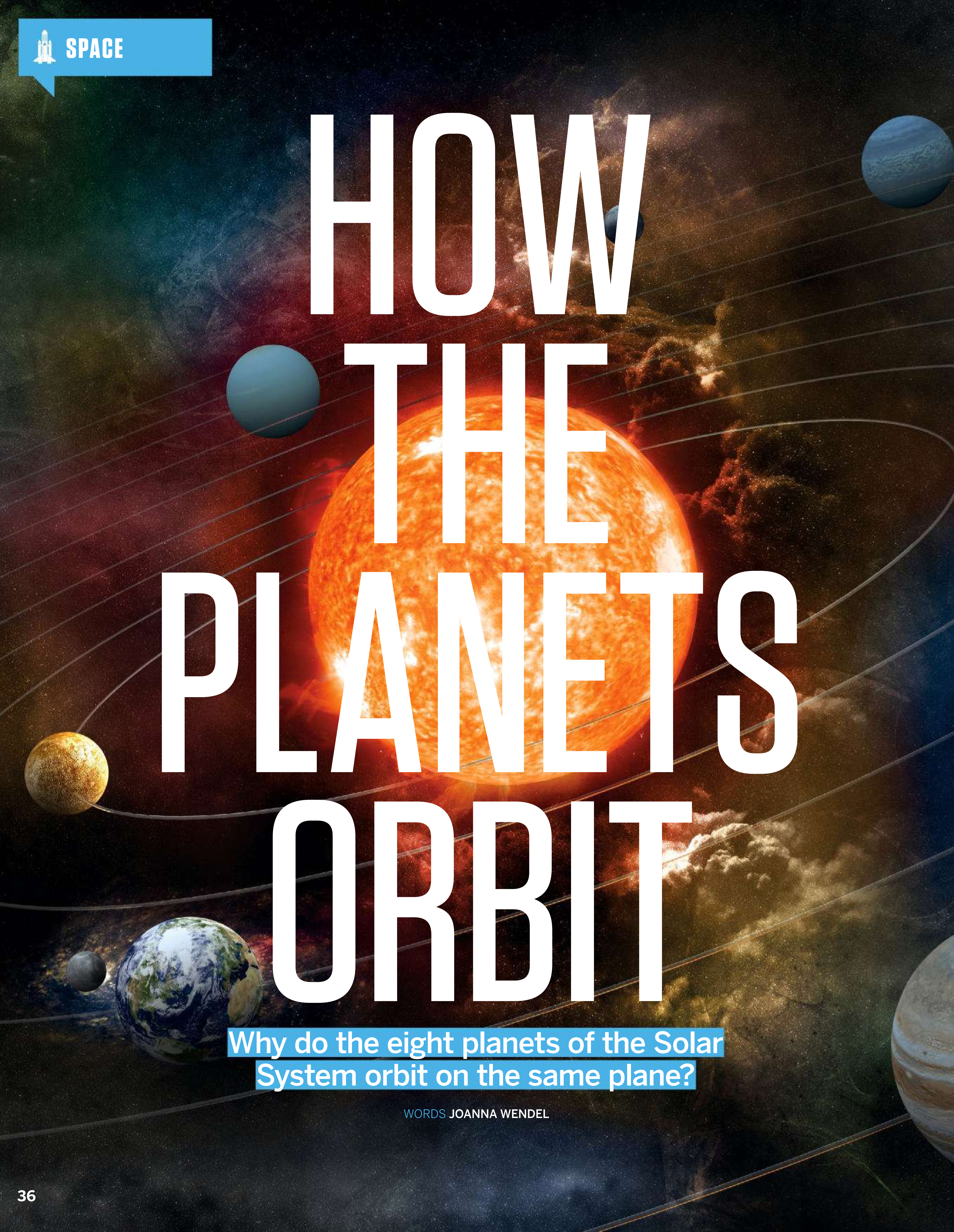
1996

Work started on the 'Next Generation Space Telescope' 25 years ago

105

There have been many successful launches of Ariane 5 before the JWST

©Getty



HOW THE PLANETS ORBIT

Why do the eight planets of the Solar System orbit on the same plane?

WORDS **JOANNA WENDEL**

DID YOU KNOW? The gravity on Jupiter is two-and-a-half times greater than on Earth

If you've ever gazed at a model of the Solar System, you've likely noticed that the Sun, planets, moons and asteroids sit roughly on the same plane. But why is that? To answer this question, we have to travel to the very beginning of the Solar System, about 4.5 billion years ago. Back then, the Solar System was just a massive, spinning cloud of dust and gas. That massive cloud measured 12,000 astronomical units (AU) across. A single astronomical unit is the average distance between Earth and the Sun, or about 93 million miles. The cloud became so big that even though it was just filled with dust and gas molecules, it started to collapse and shrink under its own mass.

As the spinning cloud of dust and gas started to collapse, it also flattened. Imagine a pizza maker throwing a spinning slab of dough into the air. As it spins, the dough expands, but becomes increasingly thin and flat. That's what happened to the very early Solar System. Meanwhile, in the centre of this ever-flattening cloud, all those gas molecules got squeezed together so much that they heated up.

Under the immense heat and pressure, hydrogen and helium atoms fused, kick-starting a nuclear reaction in the form of a baby star: the Sun. Over the next 50 million years, the Sun continued to grow, collecting gas and dust from its surroundings and burping out waves of intense heat and radiation. Slowly, the growing Sun cleared out a doughnut of empty space around it.

As the Sun grew, the cloud continued to collapse, forming a disc around the star that became ever flatter and continued to expand, with the Sun at the centre. Eventually, the cloud became a flat structure called a protoplanetary disc, orbiting around the young star. The disc stretched hundreds of AU across and was just one-tenth of that distance thick. For tens of millions of years thereafter, the dust particles in the protoplanetary disc gently swirled around, occasionally knocking into each other. Some even stuck together. Over those millions of years, the particles became millimetre-long grains, those grains became centimetre-long pebbles and the pebbles continued to collide and stick together.

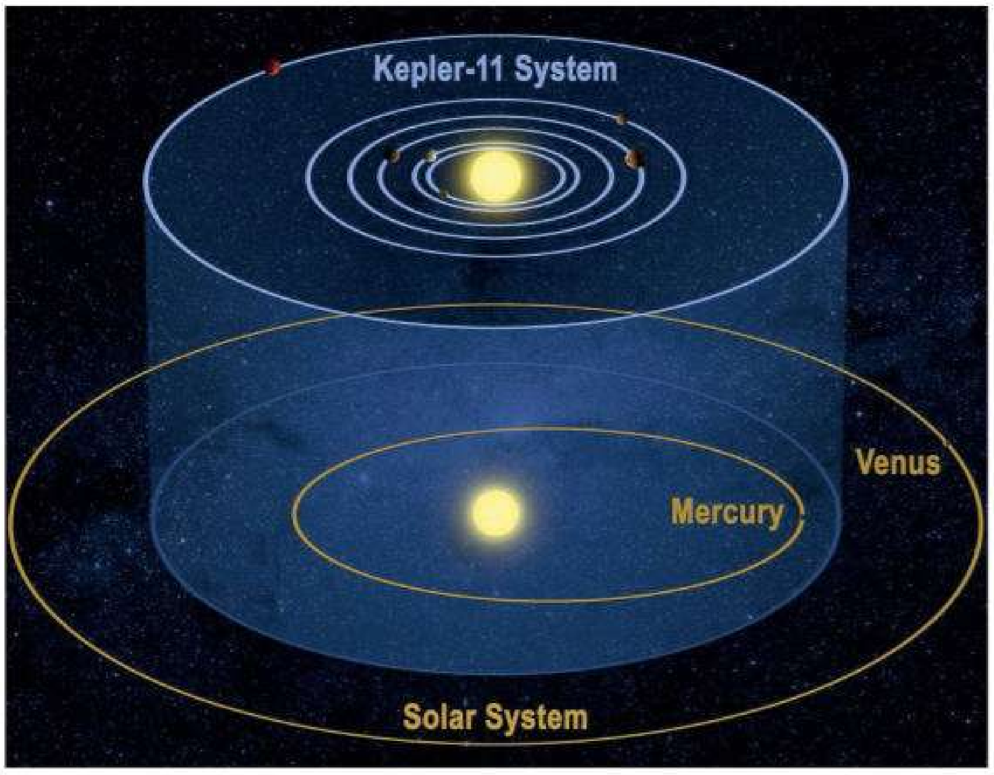
Eventually, most of the material in the protoplanetary disc stuck together to form huge objects. Some of those objects grew so big that gravity shaped them into spherical planets, dwarf planets and moons. Other objects became irregularly shaped, like asteroids, comets and some smaller moons. Despite the objects' different sizes, they stayed more or less on the same plane where their building materials originated. And that's why the Solar System's eight planets and other celestial bodies orbit on roughly the same level.

Did you know?

Saturn is so light it could float on water

SIMILAR SYSTEMS

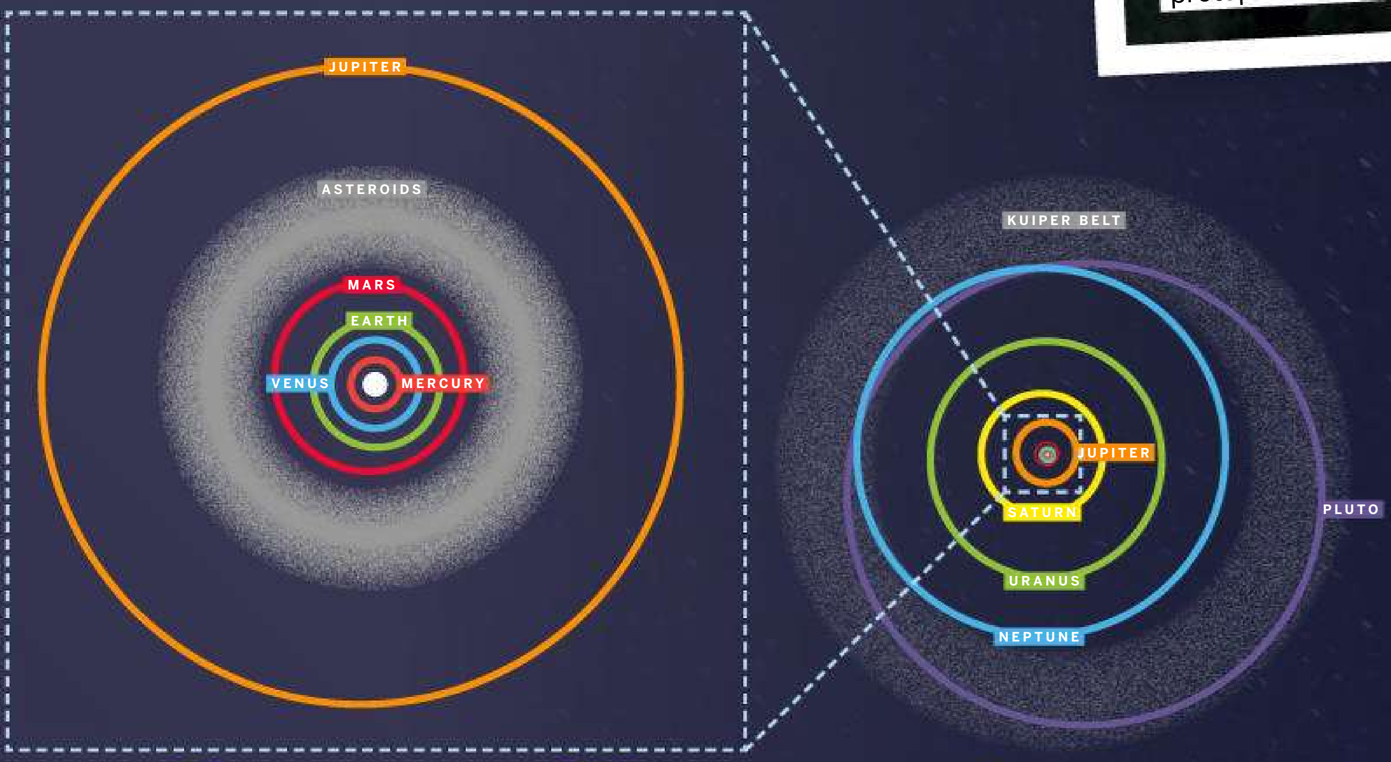
Our Solar System isn't unique. There are more than 3,200 stars in the Milky Way known to have planets orbiting them. One of the 'closest' examples is over 2,000 light years away from Earth: the Kepler-11 planetary system. Kepler-11 is the system's central star – a yellow dwarf star which is similar in size to the ice giants Uranus and Neptune. There are six known planets in this system, all of which orbit much closer to their star than most of the planets in our Solar System. The closest is Kepler-11b, which is around ten times closer to Kepler-11 than Earth is to the Sun. The outermost planet is Kepler-11g, orbiting its star from around 43 million miles away, which would place it between Mercury and Venus in our Solar System.



© Getty / NASA:Tim Pyle

ORBITING THE SUN

How the major bodies move through the Solar System



MERCURY

DISTANCE FROM SUN:
35 million miles

ONE ORBIT:
88 Earth days

ORBITAL VELOCITY:
107,082 miles per hour

VENUS

DISTANCE FROM SUN:
67 million miles

ONE ORBIT:
225 Earth days

ORBITAL VELOCITY:
78,337 miles per hour

EARTH

DISTANCE FROM SUN:
93 million miles

ONE ORBIT:
365 Earth days

ORBITAL VELOCITY:
66,615 miles per hour

MARS

DISTANCE FROM SUN:
142 million miles

ONE ORBIT:
687 Earth days

ORBITAL VELOCITY:
53,853 miles per hour

JUPITER

DISTANCE FROM SUN:
484 million miles

ONE ORBIT:
11.86 Earth years

ORBITAL VELOCITY:
29,236 miles per hour

SATURN

DISTANCE FROM SUN:
887 million miles

ONE ORBIT:
29.46 Earth years

ORBITAL VELOCITY:
21,675 miles per hour

URANUS

DISTANCE FROM SUN:
1.8 billion miles

ONE ORBIT:
84 Earth years

ORBITAL VELOCITY:
15,233 miles per hour

NEPTUNE

DISTANCE FROM SUN:
2.8 billion miles

ONE ORBIT:
164.8 Earth years

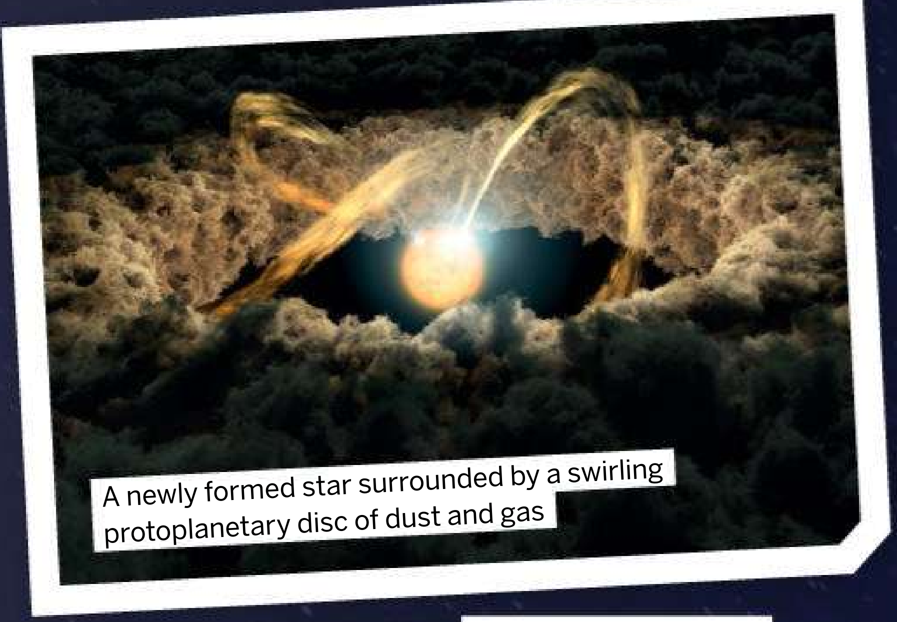
ORBITAL VELOCITY:
12,146 miles per hour

PLUTO

DISTANCE FROM SUN:
3.7 billion miles

ONE ORBIT:
248.6 Earth years

ORBITAL VELOCITY:
10,603 miles per hour

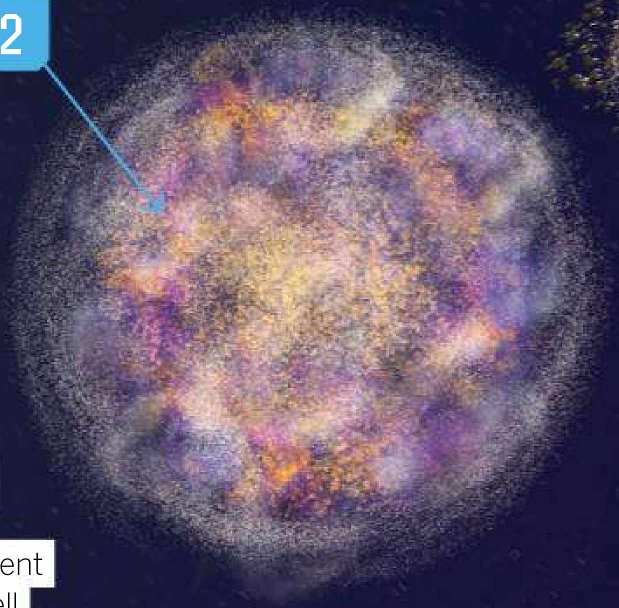


A newly formed star surrounded by a swirling protoplanetary disc of dust and gas

PRESSURE RISES

Pressure built up within this collapsing nebula, causing hydrogen atoms at the centre to transform into helium by nuclear fusion. This resulted in the release of massive amounts of energy.

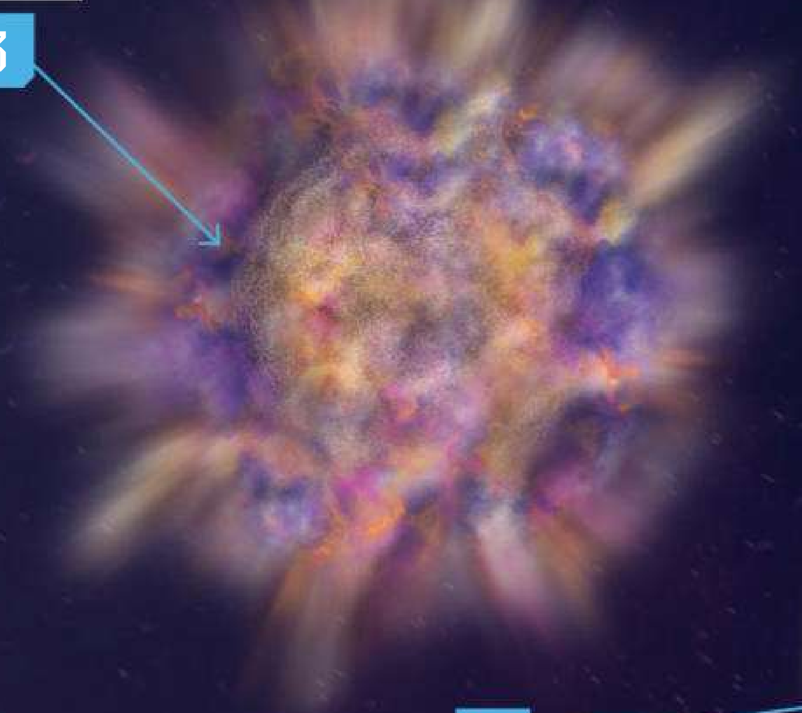
2



BUILDING BLOCKS

Around 99.8 per cent of the material fell into the centre of the cloud, forming the Sun; the remaining matter formed the Solar System as we know it.

3



Did you know?

The Sun is one of over 100 billion stars in the Milky Way

4

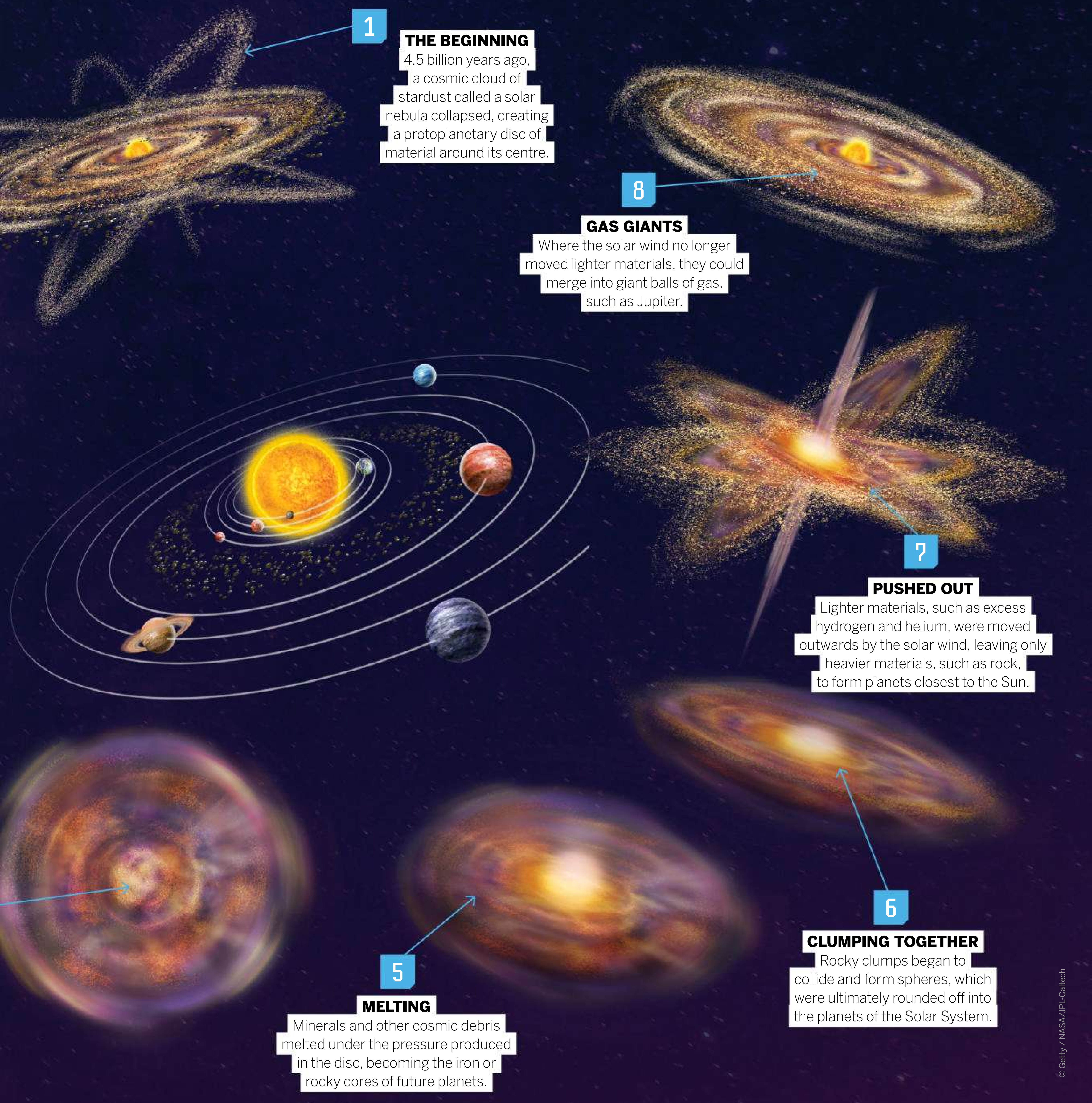
A NEW STAR

A protostar formed in the centre. Minerals and metals began to clump together under the gravity of the newly formed star.

DID YOU KNOW? There are up to 1.9 million asteroids over 0.6 miles wide in the main asteroid belt

SHAPING THE SOLAR SYSTEM

How a cloud of dust created the Sun, planets and their orbital order



1

THE BEGINNING
4.5 billion years ago, a cosmic cloud of stardust called a solar nebula collapsed, creating a protoplanetary disc of material around its centre.

8

GAS GIANTS
Where the solar wind no longer moved lighter materials, they could merge into giant balls of gas, such as Jupiter.

7

PUSHED OUT
Lighter materials, such as excess hydrogen and helium, were moved outwards by the solar wind, leaving only heavier materials, such as rock, to form planets closest to the Sun.

6

CLUMPING TOGETHER
Rocky clumps began to collide and form spheres, which were ultimately rounded off into the planets of the Solar System.

5

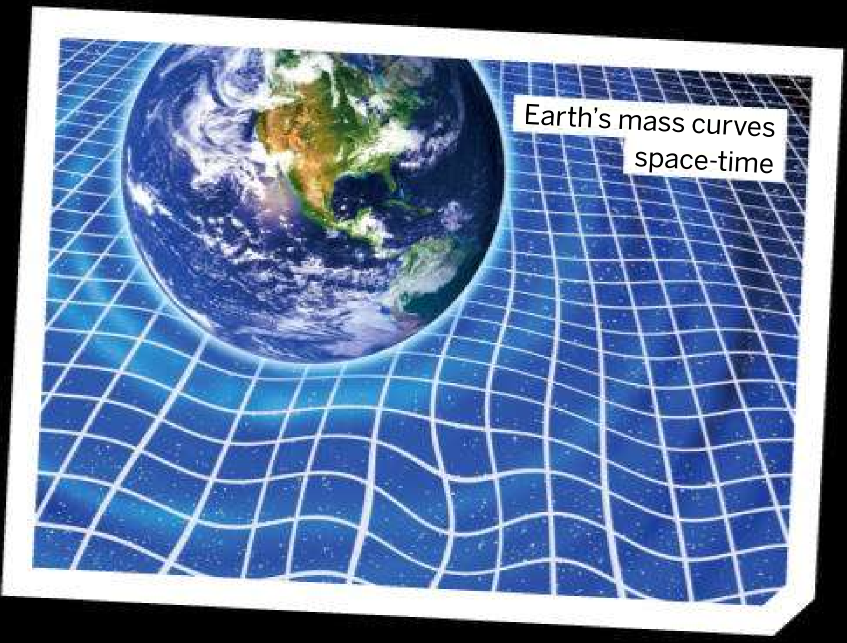
MELTING
Minerals and other cosmic debris melted under the pressure produced in the disc, becoming the iron or rocky cores of future planets.

© Getty / NASA/JPL-Caltech

WHAT IS GRAVITY?

This natural phenomenon keeps planets in orbit and our feet on the ground

WORDS **ADAM MANN**


Earth's mass curves space-time

Gravity is one of the four fundamental forces in the universe, the others being electromagnetism and the strong and weak nuclear forces. Despite being all-pervasive and important for keeping us from flying off the Earth's surface, gravity largely remains a puzzle to scientists.

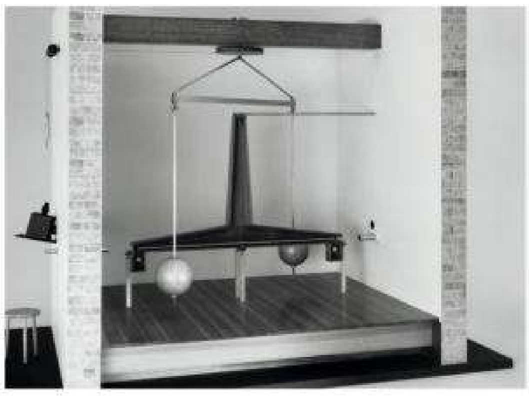
Ancient scholars trying to describe the world around them came up with their own explanations for why things fall towards the ground. The Greek philosopher Aristotle maintained that objects have a natural tendency to move towards the centre of the universe, which he believed to be the middle of the Earth.

But later luminaries dislodged our planet from its primary position in the cosmos. The Polish polymath Nicolaus Copernicus realised that the paths of the planets in the sky made much more sense if the Sun was the centre of the Solar System. The British mathematician and physicist Isaac Newton extended Copernicus' insights, reasoning that just as the Sun tugs on the planets, all objects exert a force of attraction on one another. In his famous 1687 treatise *Philosophiæ Naturalis Principia Mathematica*, Newton described what is now called his law of universal gravitation.

NOT THAT POWERFUL

Gravity is the weakest of the forces. A bar magnet will electromagnetically pull a paper clip upward, overcoming the gravitational force of the entire Earth. Physicists have calculated that gravity is 10^{40} times weaker than electromagnetism. While gravity's effects can clearly be seen on the scale of things like planets, stars and galaxies, the force of gravity between everyday objects is extremely difficult to measure. In 1798, British physicist Henry Cavendish conducted one of the world's first high-precision experiments to try to determine the value of G, the gravitational constant.

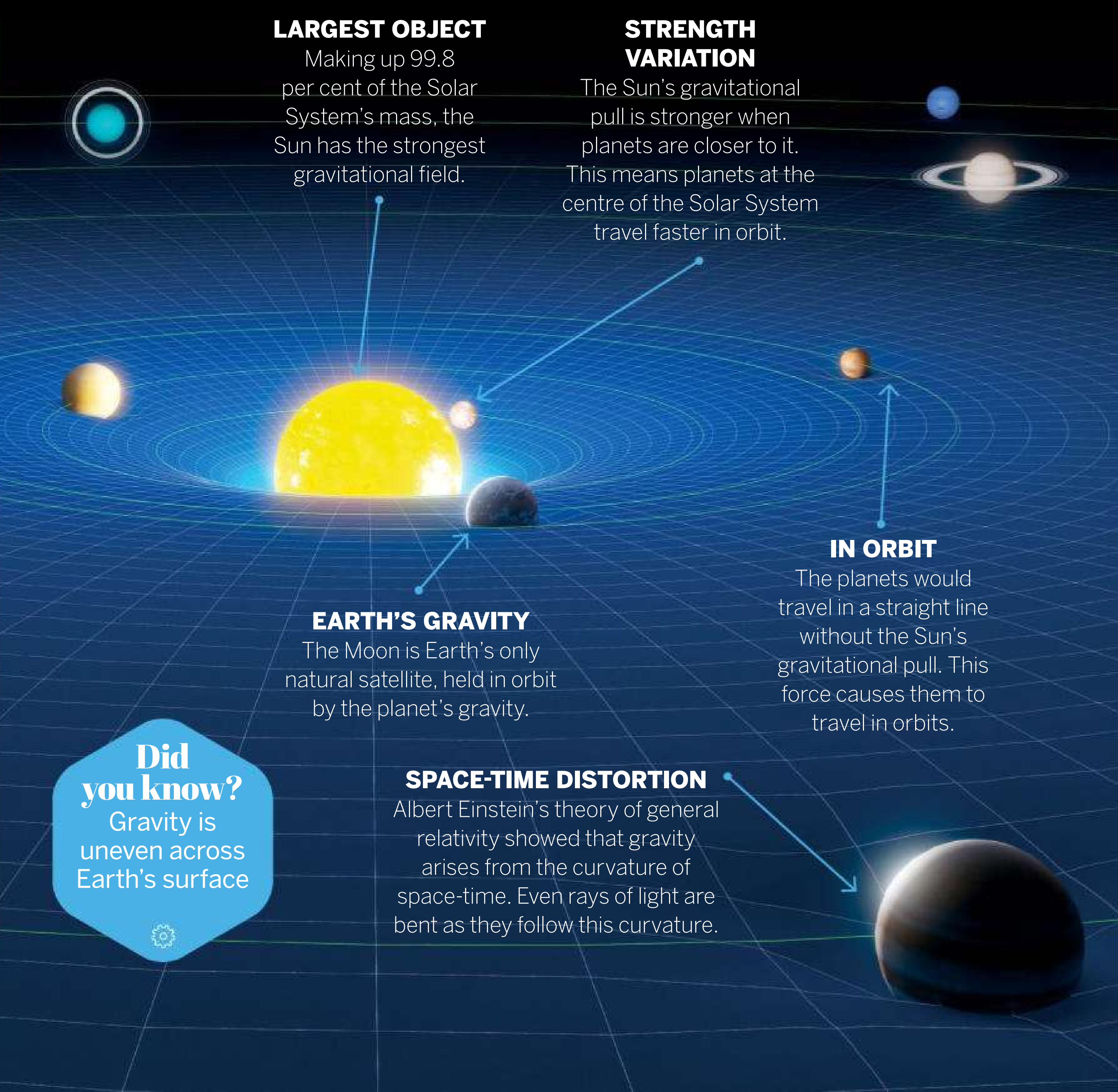
Cavendish built what's known as a torsion balance, attaching two small lead balls to the ends of a beam suspended horizontally by a thin wire. Near each of the small balls, he placed a large, spherical lead weight. The small lead balls were gravitationally attracted to the heavy lead weights, causing the wire to twist just a tiny bit and allowing him to calculate G.


A model of Cavendish's torsion balance experiment

© Alamy / Getty

EINSTEIN'S GENERAL THEORY OF RELATIVITY

Gravity's effect on the Solar System



LARGEST OBJECT
Making up 99.8 per cent of the Solar System's mass, the Sun has the strongest gravitational field.

STRENGTH VARIATION
The Sun's gravitational pull is stronger when planets are closer to it. This means planets at the centre of the Solar System travel faster in orbit.

IN ORBIT
The planets would travel in a straight line without the Sun's gravitational pull. This force causes them to travel in orbits.

EARTH'S GRAVITY
The Moon is Earth's only natural satellite, held in orbit by the planet's gravity.

SPACE-TIME DISTORTION
Albert Einstein's theory of general relativity showed that gravity arises from the curvature of space-time. Even rays of light are bent as they follow this curvature.

Did you know?
Gravity is uneven across Earth's surface

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MEET THE POISON DART FROGS

These tiny amphibians are both colourful killers and dedicated parents

WORDS SCOTT DUTFIELD

Poison dart frogs, also known as the jewels of the rainforest, are small and colourful amphibians that live on forest floors around the world. There are more than 175 species, all belonging to the family Dendrobatidae. They're often only a couple of centimetres long, are diurnal (active in the daytime) and are commonly found living in the tropical rainforests of Central and South America.

Poison dart frogs were given their name because toxins secreted from their skin have been used to tip hunters' arrows. The indigenous Emberá and Noanamá Chocó of western Colombia have used the skin of the golden poison frog (*Phyllobates terribilis*) to tip blowgun darts for hundreds of years.

These vibrant amphibians come in all colours of the rainbow. Their elaborate colourings work as an early warning to predators that they are poisonous, so an attempt to eat them would be a mistake. This survival mechanism is called aposematism, signalling to a predator that an animal is dangerous or bad tasting. Butterflies also employ this technique to stay safe. Dyeing poison dart frogs (*Dendrobates tinctorius*) use their bright yellow-and-black patterns as a form of camouflage in their natural habitat.

The variety of colours among poison dart frogs may be due to a separation in the population of their evolutionary ancestor around 10,000 years ago. The flooding of modern-day Panama thousands of years ago may have driven ancient frogs to various locations around South America, where they evolved their own colouring and body patterns.

Did you know?
The golden poison frog was discovered in 1973

The toxicity of poison dart frogs differs in severity between species. However, all of the most toxic species belong to the genus *Phyllobates*. Frogs in this genus secrete a potent toxin called batrachotoxin. The golden poison frog is often labelled the most toxic batrachotoxin-carrying frog, containing at least 20 times the amount of toxins than any other species in

DID YOU KNOW? Poison dart frogs travel as far as 400 metres to drop off tadpoles at nursery pools

PRETTY BUT DEADLY

Eight of the most toxic dart frogs on Earth

GOLDEN POISON ARROW FROG

SCIENTIFIC NAME:
Phyllobates terribilis

STATUS:
Endangered

Considered to be the most poisonous frog on the planet, the golden dart frog secretes a potent toxin that can kill a human. A single frog contains enough poison to kill more than 20,000 mice, or around ten people. The toxin typically takes effect in around ten minutes and there is no known antidote.

the dendrobatidae family. Batrachotoxin is a powerful steroidal alkaloid that interferes with the voltage-gated sodium channels in nerve and muscle cells. The brain sends instructive electrical messages to different parts of the body, which pass through these sodium channels. Batrachotoxins work to keep these channels open and disrupt the brain's messaging system, causing a whole host of debilitating and potentially fatal conditions such as paralysation, extreme pain and even cardiac failure.

There is one animal that can withstand the poison powers of the golden dart frog: the fire-bellied snake (*Liophis epinephelus*). This small reptile is the only known natural predator of dart frogs because it possesses immunity to their toxins.

Adult poison dart frogs are omnivores, but predominantly feast on insects such as ants, termites and beetles. As tadpoles their diet consists of whatever is available to them, such as algae, dead insects and in some cases other tadpoles. As opportunistic hunters, these frogs utilise a long, sticky tongue that leaps from their mouths and swipes prey in less than a second.

It's through their diet that poison dart frogs obtain their toxicity, although it remains largely unknown as to which insect is responsible for giving these frogs their poison. For the more potent members of the family, it's been suggested that melyrid beetles might be the culprit. These beetles contain high levels of batrachotoxins and have been found in the bellies of pitohui birds, which have the same secreted poison as poison dart frogs.

When raised in captivity, toxins are not obtained through their provided food, and therefore wild-caught frogs often lose the majority of their toxicity. Those bred in captivity lack any poison altogether.

DYEING POISON DART FROG

SCIENTIFIC NAME:
Dendrobates tinctorius

STATUS:
Least concern

The dyeing frog can be found on the forest floors of Brazil and Guyana. This dual-toned frog gets its name from a technique called tapirage, whereby the frog's skin is used by the people of the Amazon to dye the feathers of parrots.

© Alamy / Getty

LOVELY POISON FROG

SCIENTIFIC NAME:
Phyllobates lugubris

STATUS:
Least concern

As the frog with the lowest amount of toxins in the *Phyllobates* family, this poison frog is the best of a toxic bunch. Their skin secretions consist of an alkaloid called pumiliotoxin. This toxin affects the calcium channels in muscle tissue, including the heart and skeletal muscles.

GOLFODULCEAN POISON FROG

SCIENTIFIC NAME:
Phyllobates vittatus

STATUS:
Vulnerable

Found throughout Costa Rica, these stripy frogs typically dwell between tree roots or hide in rock crevices. Although a member of the Phyllobates genus, these frogs are more dangerous to other animal predators than humans. Snakes have been witnessed seizing them and experiencing muscular distress for hours after.

KOKOE POISON FROG

SCIENTIFIC NAME:
Phyllobates aurotaenia

STATUS:
Least concern

Along with the golden dart frog and the black-legged poison frog, Kokoe poison frogs are one of only three species of frog to be used to tip the blowguns of Chocó tribes in western Colombia. Like its poisonous cousins, the Kokoe poison frog is laced in alkaloid toxins that can cause cardiac arrhythmias and heart failure.

BLACK-LEGGED POISON FROG

SCIENTIFIC NAME:
Phyllobates bicolor

STATUS:
Endangered

This species is often referred to as the second-deadliest dart frog. There are 17 to 56 micrograms of toxins per frog, compared to the 700 to 1,900 micrograms found in golden dart frogs. The toxins are so potent that they persist in wild-caught frogs that are kept in captivity.

BUMBLEBEE POISON FROG

SCIENTIFIC NAME:
Dendrobates leucomelas

STATUS:
Least concern

Also known as the yellow-banded poison dart frog, these amphibians can be found across the Neotropical region of South America. As adults these frogs feast on insects, but as tadpoles they are sometimes cannibalistic. This typically occurs when separate frog parents place offspring in the same nursery pool.

GREEN-AND-BLACK POISON FROG

SCIENTIFIC NAME:
Dendrobates auratus

STATUS:
Least concern

These colourful frogs can be found in heavily populated areas of Hawaii around streams and pools, where they lay their eggs. Green-and-black poison frogs reach adulthood around eight weeks after hatching. Their poisonous skin is thought to be due to an ant-filled diet, providing them with the alkaloids they need to produce toxins.

Did you know?
Phantasmal poison frogs can live for around 20 years

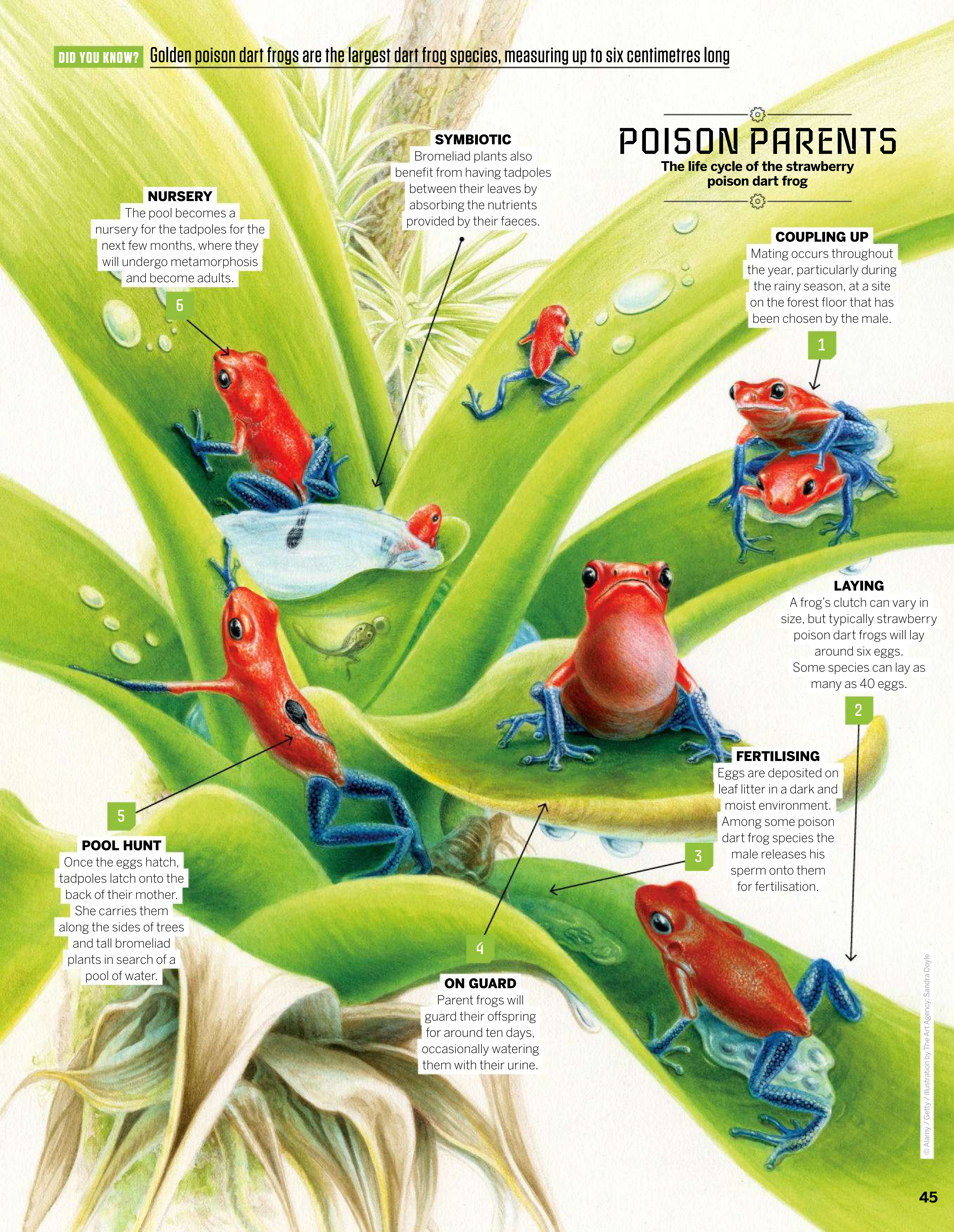
STOPPING SELF-SABOTAGE

If poison dart frogs don't manufacture their own toxins, then why aren't they poisoned when they consume their prey? There are many theories to explain the toxic resistance of these frogs. One is that their anatomy includes genetically mutated sodium channels that prevent the toxin from binding and affecting them. Another method, employed by many predators of poisonous animals, is to simply remove the toxin from the body quickly after consumption. However, more recent studies have suggested that poison dart frogs have 'toxin sponge' protein molecules that prevent the batrachotoxin from binding with sites on the frog's cells, thus providing them with immunity to the poison they carry.

DID YOU KNOW? Golden poison dart frogs are the largest dart frog species, measuring up to six centimetres long

POISON PARENTS

The life cycle of the strawberry poison dart frog



COUPLING UP
Mating occurs throughout the year, particularly during the rainy season, at a site on the forest floor that has been chosen by the male.

LAYING
A frog's clutch can vary in size, but typically strawberry poison dart frogs will lay around six eggs. Some species can lay as many as 40 eggs.

FERTILISING
Eggs are deposited on leaf litter in a dark and moist environment. Among some poison dart frog species the male releases his sperm onto them for fertilisation.

ON GUARD
Parent frogs will guard their offspring for around ten days, occasionally watering them with their urine.

POOL HUNT
Once the eggs hatch, tadpoles latch onto the back of their mother. She carries them along the sides of trees and tall bromeliad plants in search of a pool of water.

NURSERY
The pool becomes a nursery for the tadpoles for the next few months, where they will undergo metamorphosis and become adults.

SYMBIOTIC
Bromeliad plants also benefit from having tadpoles between their leaves by absorbing the nutrients provided by their faeces.

© Alamy / Getty / Illustration by The Art Agency; Sandra Doyle

THE MOST POLLUTED PLACES ON EARTH

Discover the areas smothered by smog, poisoned by plastic and recovering from radiation

SCOTT DUTFIELD

DID YOU KNOW? Over the last 30 years, toxic particulate matter in the air has fallen in the UK

By-products of industry fill the air

Pollution is the introduction of a substance into an environment that results in damage, interferes with ecosystems or endangers human health. The word 'pollution' stems from the 14th century and comes from the Latin word 'polluere', meaning to soil or defile. However, it wasn't until the Industrial Revolution that the effects of human activities on the environment began to show, particularly the reduction in air quality.

Since then, pollution has become one of the biggest threats to our environment, massively impacting the health of humans all over the world. Millions of people die prematurely each year from diseases caused by air pollution. For example, in the UK alone around 36,000 deaths are caused by air pollution each year.

Air quality is measured by the amount of particulate matter in the air – predominantly those that are smaller than 2.5 micrometres (PM2.5). These fine particles are responsible for causing a range of conditions and diseases, such as heart disease and cancer. Particles smaller than 2.5 micrometres can enter the bloodstream and worsen fatty buildup in the arteries. This has the potential to disrupt the functioning of the heart.

Air pollution is just one of many different types of pollution, which all contribute to destroying our environments. Other forms include water, land and plastic pollution. Chemical leachates from waste or oil spills compromise water quality and impact human health. It's estimated that 4,000 children die every day from polluted drinking water. Similarly, contaminated land waste, such as deposits in landfill sites or runoff from agriculture, can leach toxic chemicals into the soil system. These leachates then migrate through vegetation and enter the food chain.

Did you know?
The Industrial Revolution began around 1760

GLOBAL POLLUTION BY NUMBERS

4.2 million
Deaths caused by air pollution globally every year

9/10
The majority of people on Earth are exposed to air pollution levels that can increase risk of diseases

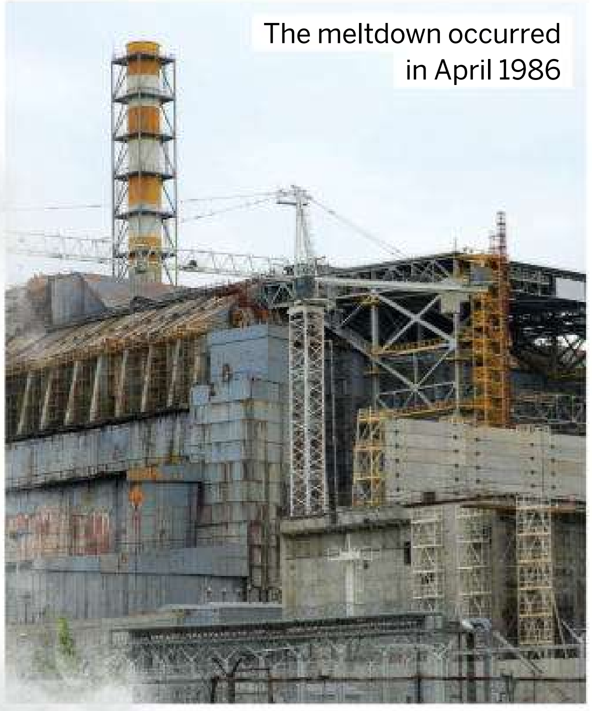
Oil tanker accidents account for 10 to 15 per cent of all oil that enters the ocean each year

10 million tonnes
Five times the UK's annual plastic consumption is dumped into the ocean every year

1 million
The number of marine animals killed by plastic each year

46,000 pieces
Every square mile of ocean contains plastics weighing up to 269,000 tonnes

386 billion litres
The US releases over 150,000 Olympic Swimming pools of untreated water annually into the environment


The meltdown occurred in April 1986

THE CHERNOBYL DISASTER'S LEGACY

35 years after the infamous explosion at the Chernobyl Nuclear Power Plant, radioactive fallout is still present. 58,000 square miles of land in Belarus, Russia and Ukraine remains classified as contaminated, and the 1,100 square miles closest to the power plant is considered an exclusion zone.
In April 2020, fears about the levels of radioactivity in Chernobyl reignited when wildfires ripped through exclusion zone forests. This caused radiation levels to spike more than 17 times the normal background levels, as the burning trees released previously absorbed radioactive elements such as plutonium-238 and caesium-137.

© Getty

POLLUTION HOTSPOTS

Here are some of the most polluted places on Earth

LAHORE
PAKISTAN

The tall buildings of Pakistan's second-largest city are often concealed by dense rolling smog, created from a combination of vehicle and industrial emissions. Lahore frequently ranks at the top of the most polluted cities around the world for its air quality. During 2020, Lahore's PM2.5 average was 79.2 micrograms per cubic metre. Air pollution is a sizable problem in Pakistan, accounting for an estimated 128,000 deaths each year.

NIGER RIVER DELTA
NIGERIA

Since the mid-20th century, this 27,000 square mile region of Nigeria has been polluted with petroleum. Around 240,000 barrels of crude oil – equal to around 40 million litres – are spilled each year. Large-scale oil extraction by energy companies such as Shell began in the area in 1956. Since then, mangrove swamps that would have been bursting with wildlife have been choked with thick oil from operational spills.

MATANZA-RIACHUELO
ARGENTINA

The waste and sewage pumped out from tanneries, chemical plants and factories has created Argentina's most polluted waterways. The Matanza-Riachuelo River Basin runs over 37 miles, spanning an area around 5,700 square miles, and is home to at least 15,000 small industries that feed pollutants, including heavy metals, into its waters. It's reported that 25 per cent of children living in the urban slums around the Riachuelo's basin have lead in their bloodstream. In 2019, the World Bank board of directors approved two loans totalling $395 million (£286 million) to projects constructing better sanitation infrastructure around the river.

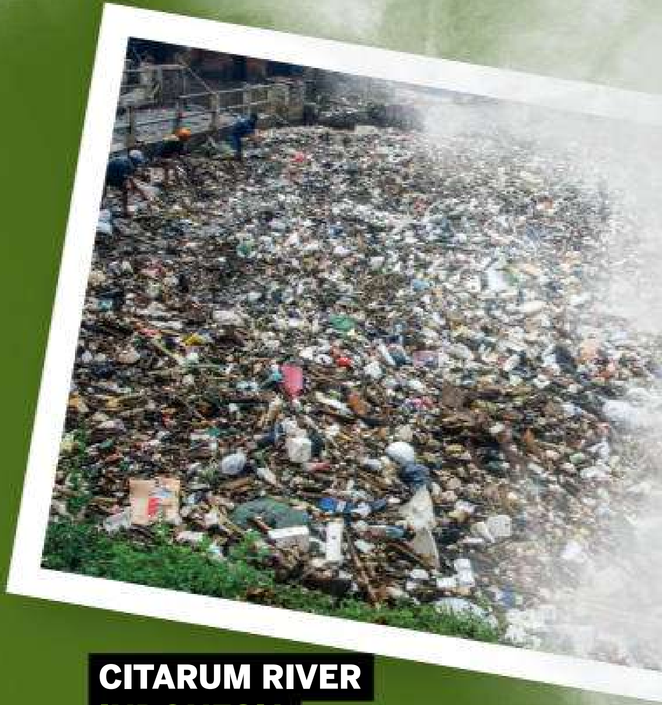
AGBOGBLOSHIE
GHANA

Welcome to the world's largest digital dumping ground. On the banks of the Korle Lagoon, heaps of 'e-waste' dominate the landscape; discarded refrigerators, crushed car parts and cracked computers appear to be permanent neighbours of the 80,000 residents. Only 20 per cent of e-waste is recycled worldwide – the rest enters dumping sites. The waste is tackled by burning it, resulting in toxic smoke billowing into the air.

DID YOU KNOW? More than 22 million people live in areas with unsafe PM2.5 levels

NORILSK
RUSSIA

Norilsk is an industrial city that was founded in 1935. It was once home to one of the world's largest heavy metal smelting plants. Historically the city has been the source of large-scale pollution, with millions of tonnes of heavy metals such as zinc, lead and even arsenic released into the atmosphere. In May 2020, more than 20,000 tonnes of diesel fuel was spilled into the water and soil of Norilsk's Ambarnaya River. The fuel storage tank belonged to Norilsk Nickel, one of Russia's largest nickel, platinum and copper producers.



CITARUM RIVER
INDONESIA

In the West Java province of Indonesia runs one of the world's most polluted rivers, the Citarum. This river has 5,000 times the mandatory limit of faecal coliform bacteria and 1,000 times the acceptable level of lead set by the US Environmental Protection Agency. The river's high level of pollution comes from industrial waste and sewage overflow. Since 2009 the number of fish in the river has decreased by 60 per cent. Although the river is highly polluted, it still provides treated drinking water for millions of people in cities such as Bandung, Cianjur and Bekasi. The water also flows into three reservoirs to generate electricity for Java and the Bali province.

GHAZIABAD
INDIA

This industrial city has the second-worst air quality in the world. The streets of Ghaziabad fill with smoke, dust and noxious haze, born from human activity and the city's topography. There are over 34 million residents of Ghaziabad, and through large amounts of nitrogen dioxide vehicle emissions and city expansion, the city has been left with a PM2.5 average of 106.6 micrograms per cubic metre. Guidelines set out by the World Health Organization (WHO) state that annual mean concentrations of PM2.5 shouldn't exceed five micrograms per cubic metre.

HAZARIBAGH
BANGLADESH

At the heart of Bangladesh's capital city, Dhaka, is an industrial area called Hazaribagh. Hazaribagh is a hotspot for chromium pollution from the 150 tanneries that were once found in the region. Heavy metals such as chromium are by-products of the process of tanning leather, and are often suspended in wastewater. Around 22,000 cubic litres of toxic waste, including chromium, is dumped in Hazaribagh's main river every day. Despite the tanning industry relocating out of the area in 2017, water and soil samples show that chromium contamination still poses a threat to groundwater quality.

© Getty

CAMEL ANATOMY: HUMPS TO HOOVES

This mammal's unique features allow it to thrive in desolate lands

WORDS **AILSA HARVEY**

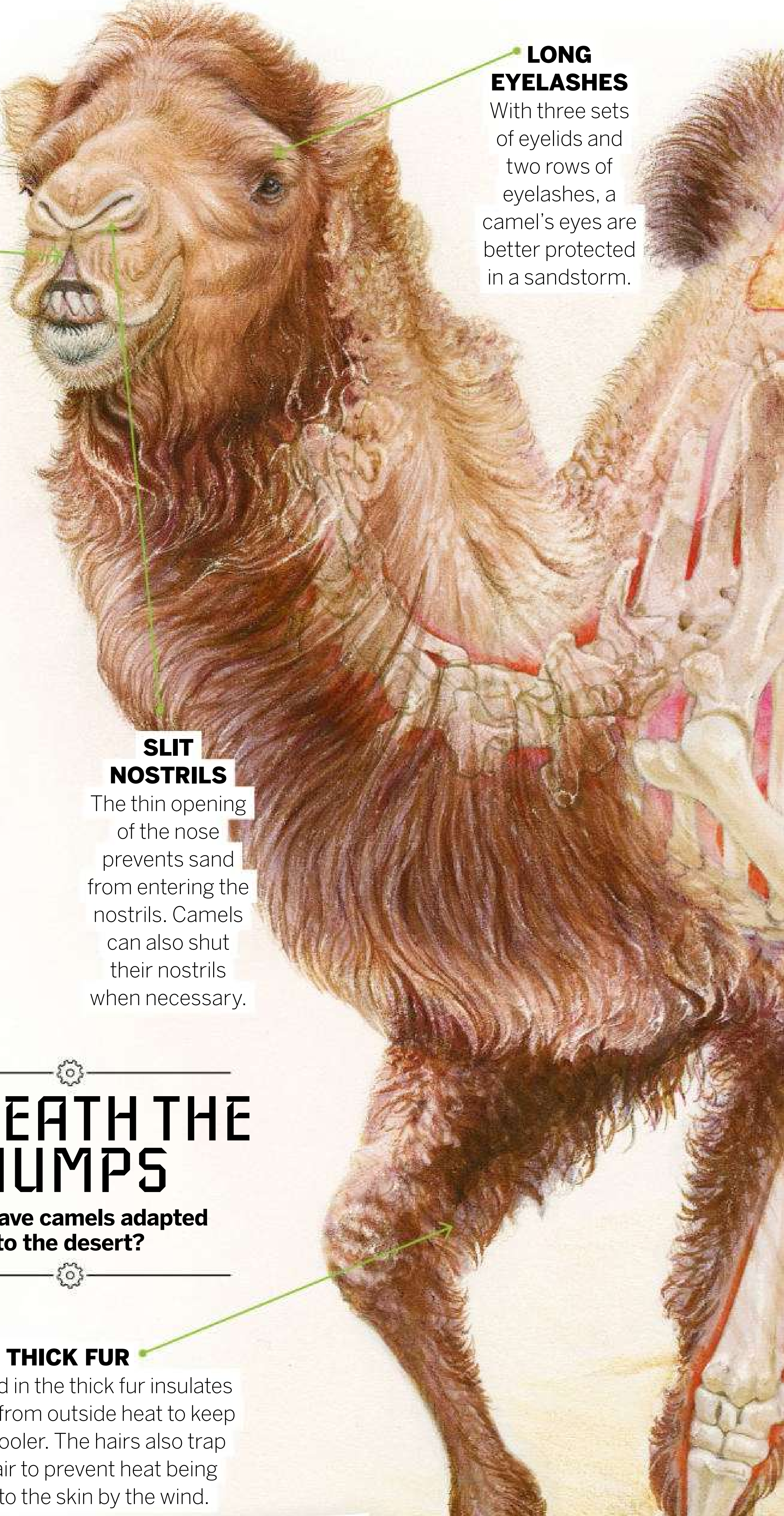
Like its own biological survival backpack, a camel's hump provides it with energy during prolonged periods of famine in barren environments. These distinctive protruding mounds store up to 36 kilograms of fat each. Depending on the species, a camel can have one, two or sometimes more of these lifesaving adaptations. When camels are unable to find food or water and begin to run out of energy from their last meal, they extract energy, vitamins, minerals and some moisture from their humps. This method has kept some camels alive for months without eating.

Instead of distributing their fat more evenly around their bodies, camels are the only animals that store it in great lumps. Without this even layer of insulation, heat can escape camels' bodies more easily, preventing their body temperature from rising too high.

These animals' bodies are tailored towards hot, dry habitats, mainly in sandy deserts around the equator. But some of their ancestors lived very different lives. Mummified remains of camel legs found in 2013 confirmed that these animals once roamed the Arctic tundra. This may have been how camels first developed their humps and became experts at living in extremes. 3 million years ago, camels survived in icy conditions with similar anatomy, which today helps them thrive in deserts. Energy reserves in their fatty humps enabled them to survive when skies were dark for months at a time and food was less accessible. This also gave them an advantage over other species when the Ice Age started, as they could outlive them on the same resources.

BENEATH THE HUMPS

How have camels adapted to the desert?

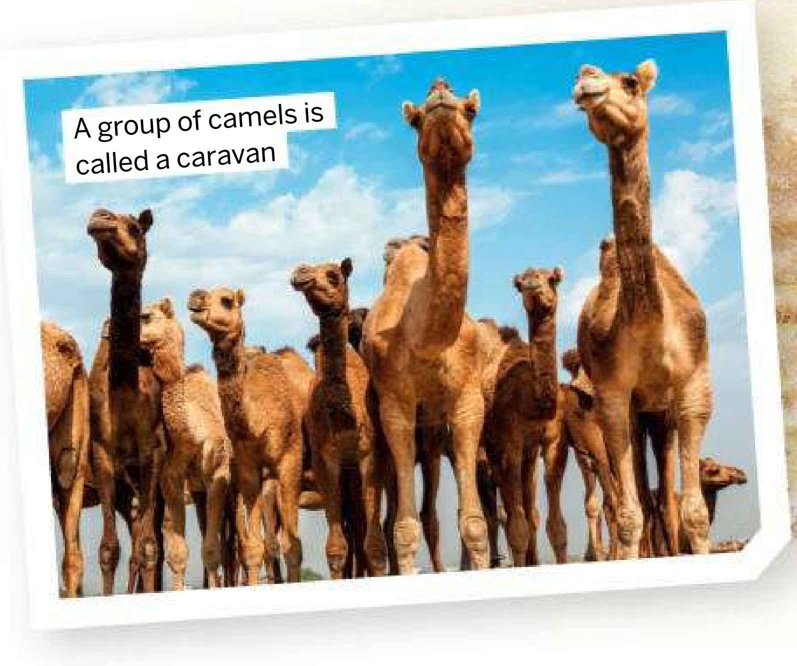


SPLIT LIP
The top lip is parted so that any moisture leaving the camel through its nostrils is directed into its mouth, reducing dehydration.

LONG EYELASHES
With three sets of eyelids and two rows of eyelashes, a camel's eyes are better protected in a sandstorm.

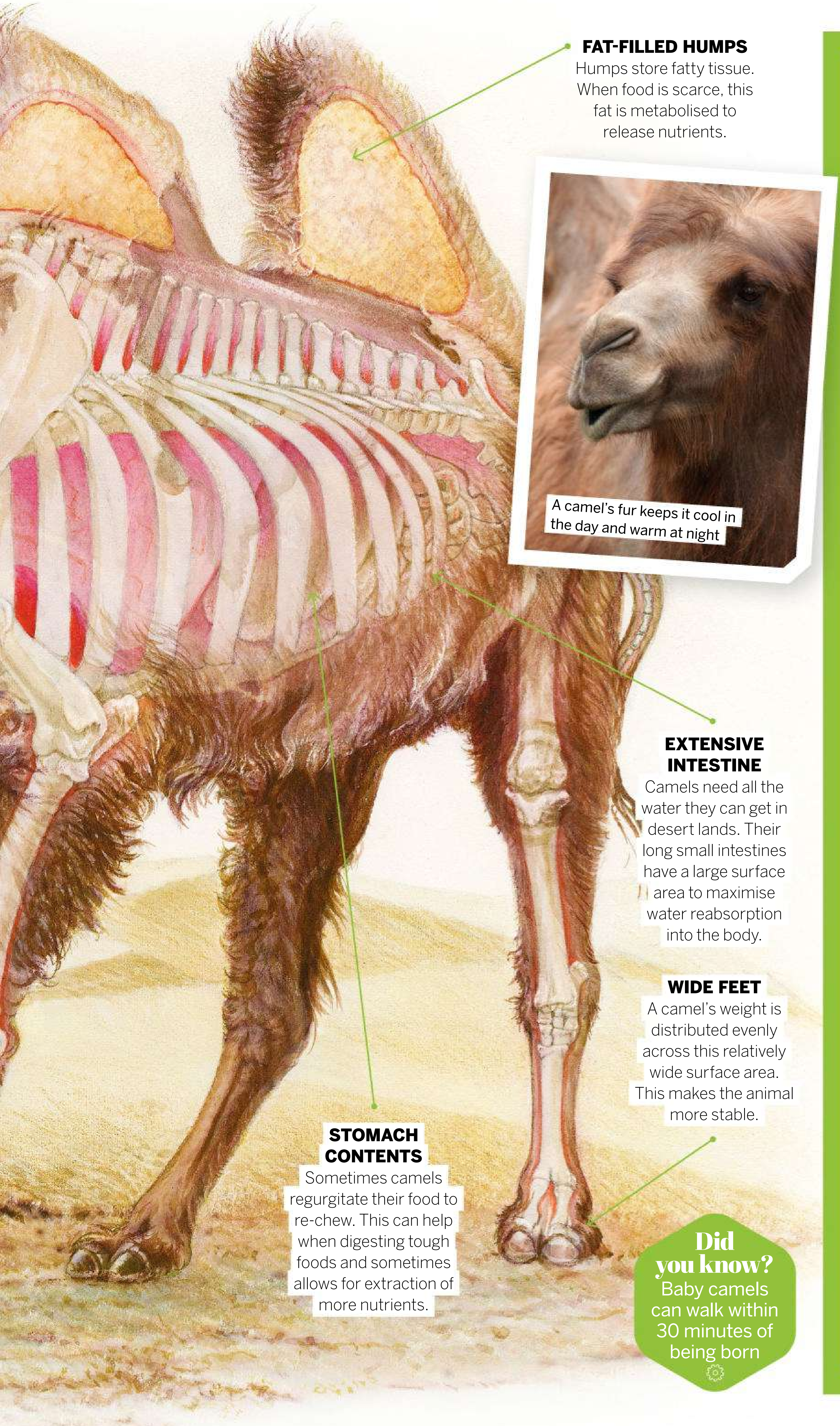
SLIT NOSTRILS
The thin opening of the nose prevents sand from entering the nostrils. Camels can also shut their nostrils when necessary.

THICK FUR
Air trapped in the thick fur insulates the camel from outside heat to keep the skin cooler. The hairs also trap moving air to prevent heat being carried to the skin by the wind.



A group of camels is called a caravan

DID YOU KNOW? A camel can drink a quarter of its own weight in water at a time



FAT-FILLED HUMPS
Humps store fatty tissue. When food is scarce, this fat is metabolised to release nutrients.

A camel's fur keeps it cool in the day and warm at night

EXTENSIVE INTESTINE
Camels need all the water they can get in desert lands. Their long small intestines have a large surface area to maximise water reabsorption into the body.

WIDE FEET
A camel's weight is distributed evenly across this relatively wide surface area. This makes the animal more stable.

STOMACH CONTENTS
Sometimes camels regurgitate their food to re-chew. This can help when digesting tough foods and sometimes allows for extraction of more nutrients.

Did you know?
Baby camels can walk within 30 minutes of being born

WHAT'S ON A DESERT MENU?

When food is limited, animals can't afford to be fussy eaters. Camels are herbivores and rely on desert shrubs, grasses and twigs. Their mouths are tough and able to withstand thorns, but their lips remain flexible enough to grab and break off food.

Their stomachs have three or four chambers, which can prolong digestion to thoroughly break down tougher meals. The increased surface area of the stomach means moisture in the plants they eat can be better absorbed before leaving the body. Eating plumps up camels' humps, and after a long time without food they will shrink.

Camels can eat cactuses by grinding sharp thorns on their mouth palate

CAMEL BEHAVIOUR

Camels are social animals, often traversing deserts in male-led groups. When greeting each other, they're known to blow in each other's faces. Different noises are made when camels 'talk' to each other. These include moans and hums. When a female camel gives birth, she usually separates herself from the herd. The mother looks after the calf alone before rejoining the herd two weeks later. For the next 10 to 12 months she will produce milk for her young.

Female camels need to find enough food to produce milk for their young

© Alamy / Getty

SUPER TRACTORS

WORDS AILSA HARVEY

From the greatest in size and speed to the latest autonomous tech, could these tractors change the way we farm?

Methods used in farming are constantly changing. In the 1950s, for example, the increased use of pesticides, herbicides and fertilisers drastically improved crop yield, becoming known as the Green Revolution. But arguably the biggest 20th-century agricultural development was the arrival of the tractor. These vehicles replaced the animal power we previously relied on. Machinery excelled in fields; tractors could carry more across longer distances for longer periods of time, and even turn the soil. Farmers no longer needed to use large swathes of their land to grow food for the working animals.

Tractors are evolving as new tools expand the boundaries of farming. Whether you're looking for technology that tackles a vehicle's speed, maximises the number of tractors that can work at once or limits wasted resources, there are many features to consider when choosing a tractor today.

Running a farm and growing produce requires extensive manual labour, and as advanced machinery increases farmers' yields and farms grow in size, the workload increases as well. In recent years, autonomous technology has meant that vehicles and machines no longer need to be tethered to a human driver. Instead of every change in speed, steering, braking and navigation being initiated by the farmer, intelligent computers can automatically perform this series of movements without much external input.

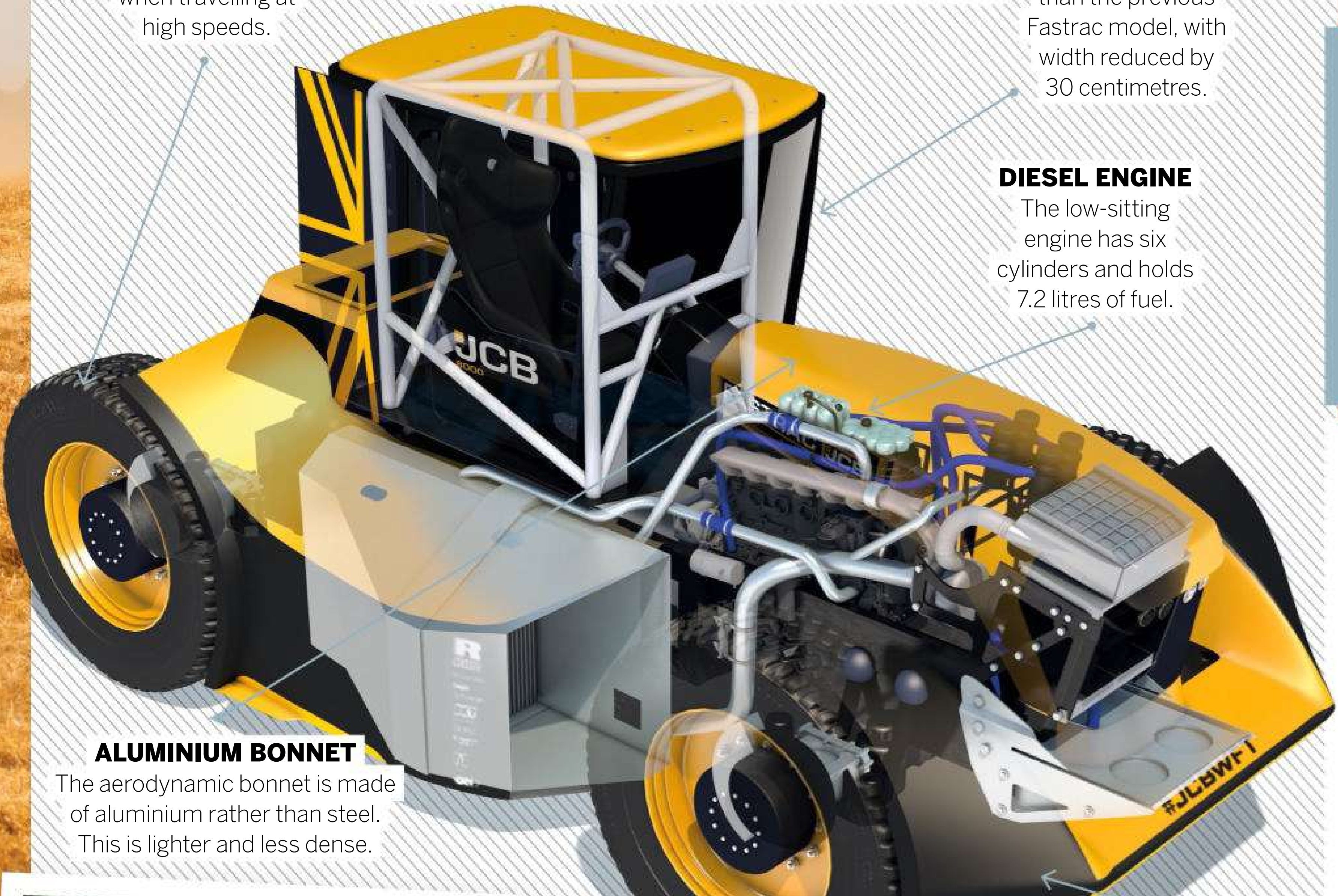
In the future, driverless machines are likely to take on different roles around farms, with people controlling and preplanning the vehicles' daily movements. Some farmers welcome these 'super tractors' as a way to increase productivity while they focus on managing the farm, while others prefer more traditional methods. What today's tractors are providing, however, is choice and versatility in farming.

Above: GPS tracking is used to locate autonomous tractors

Opposite: A Fastrac Two's average speed is 135 miles per hour

WORLD'S FASTEST

The JCB Fastrac Two is engineered to reach speeds of over 150 miles per hour



TYRE STRENGTH
Steel cylinders at the centre of the tyres add strength, needed when travelling at high speeds.

REDUCED SIZE
Its height is 20 centimetres lower than the previous Fastrac model, with width reduced by 30 centimetres.

DIESEL ENGINE
The low-sitting engine has six cylinders and holds 7.2 litres of fuel.

ALUMINIUM BONNET
The aerodynamic bonnet is made of aluminium rather than steel. This is lighter and less dense.

LIGHTER CHASSIS
The chassis rails, extending the length of the tractor, are half the weight of the previous Fastrac vehicle's.

> "Driverless machines are likely to take on different roles around farms"

BIG BUD

The biggest tractor ever built is the Big Bud 16V-747. Measuring 8.5 metres long and six metres wide, this king of the fields gained its title when it was first built in 1977, and has retained it ever since. When Big Bud's fuel tank is full, the tractor weighs more than 45,000 kilograms – that's six times as heavy as an elephant.

The vehicle's sheer size means that Big Bud can farm three acres of land in one minute. While there were multiple Big Bud tractors manufactured, only one of the largest models was built. Brothers Robert and Randy Williams, who own Big Bud, used the tractor for cultivating until one of its tyres sustained irreparable damage and it was put out of service. The brothers restored Big Bud with new tyres, allowing the largest tractor to continue operation.

Did you know?
To the top of the cab, Big Bud is 4.3 metres tall

The Big Bud 747 was built in Montana

AR zone
SCAN HERE

5 TRACTORS OF THE YEAR

1 2021
MASSEY FERGUSON 8S.265
This tractor's standout feature is its cab: it's quiet, it provides increased visibility with its large glass panes and supports connectivity with other farm vehicles.

2 2020
FENDT 942 VARIO
This won Tractor of the Year as well as Best All-Purpose Tractor. It was found to manage power output well at particularly low speeds.

3 2019
CASE IH MAXXUM 145 ACTIVEDRIVE 8
The 2019 winner achieved the lowest fuel use in its class. The 145's power transmission incorporates eight powershift steps, providing 24 different speeds in both forward and reverse.

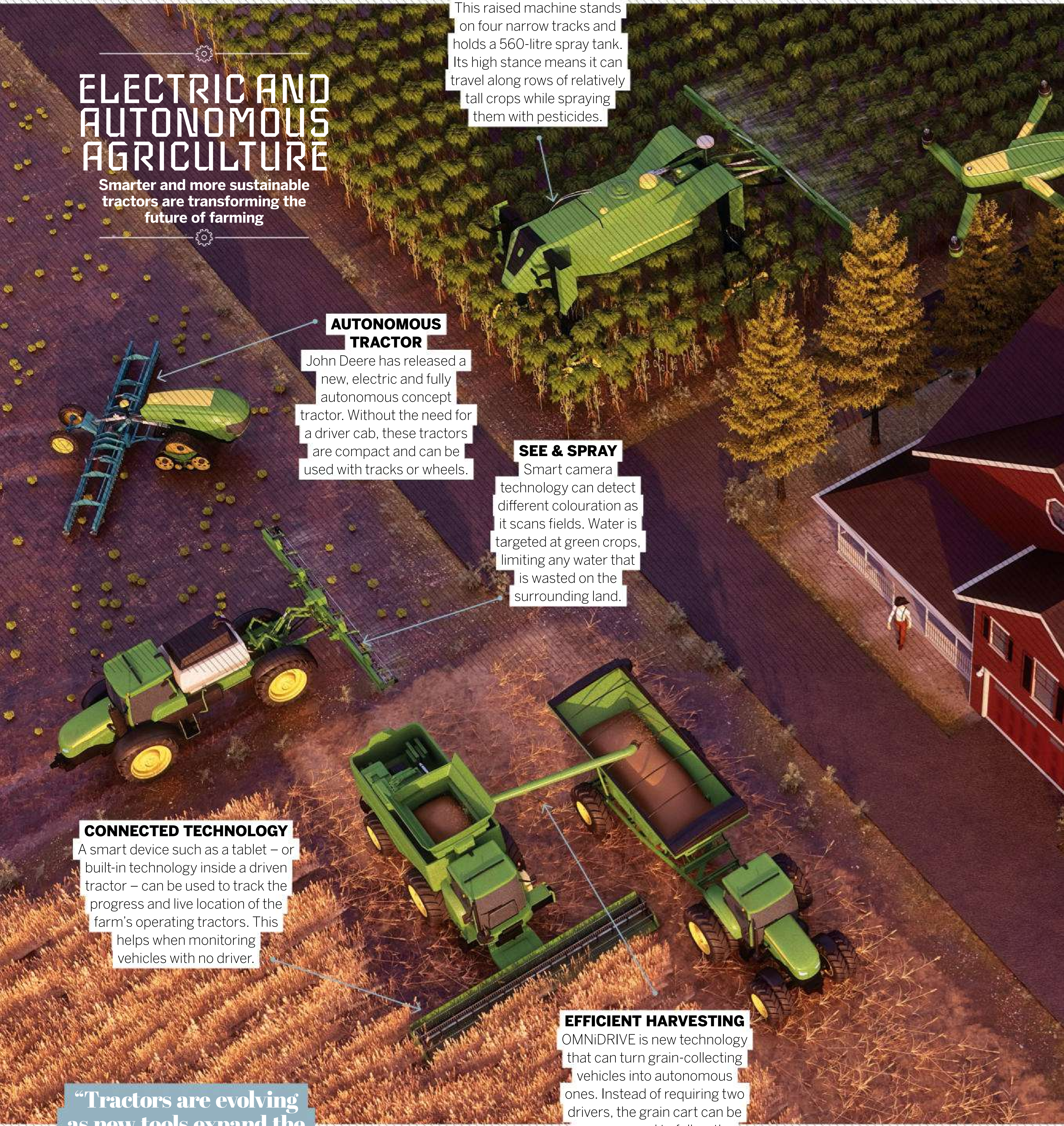
4 2018
VALTRA VERSU T254 SMART TOUCH
With a 23-centimetre touchscreen, the armrest in this tractor allows the operator to adjust and preplan the tractor's settings.

5 2017
CASE IH OPTUM 300 CVX
This high-power tractor has a modern look, and in 2017 was lighter and more compact than similar models.

© Alamy / Getty / Wiki: Myron Reynard/Illustration by Adrian Mann

ELECTRIC AND AUTONOMOUS AGRICULTURE

Smarter and more sustainable tractors are transforming the future of farming



DRIVERLESS SPRAYER
This raised machine stands on four narrow tracks and holds a 560-litre spray tank. Its high stance means it can travel along rows of relatively tall crops while spraying them with pesticides.

AUTONOMOUS TRACTOR
John Deere has released a new, electric and fully autonomous concept tractor. Without the need for a driver cab, these tractors are compact and can be used with tracks or wheels.

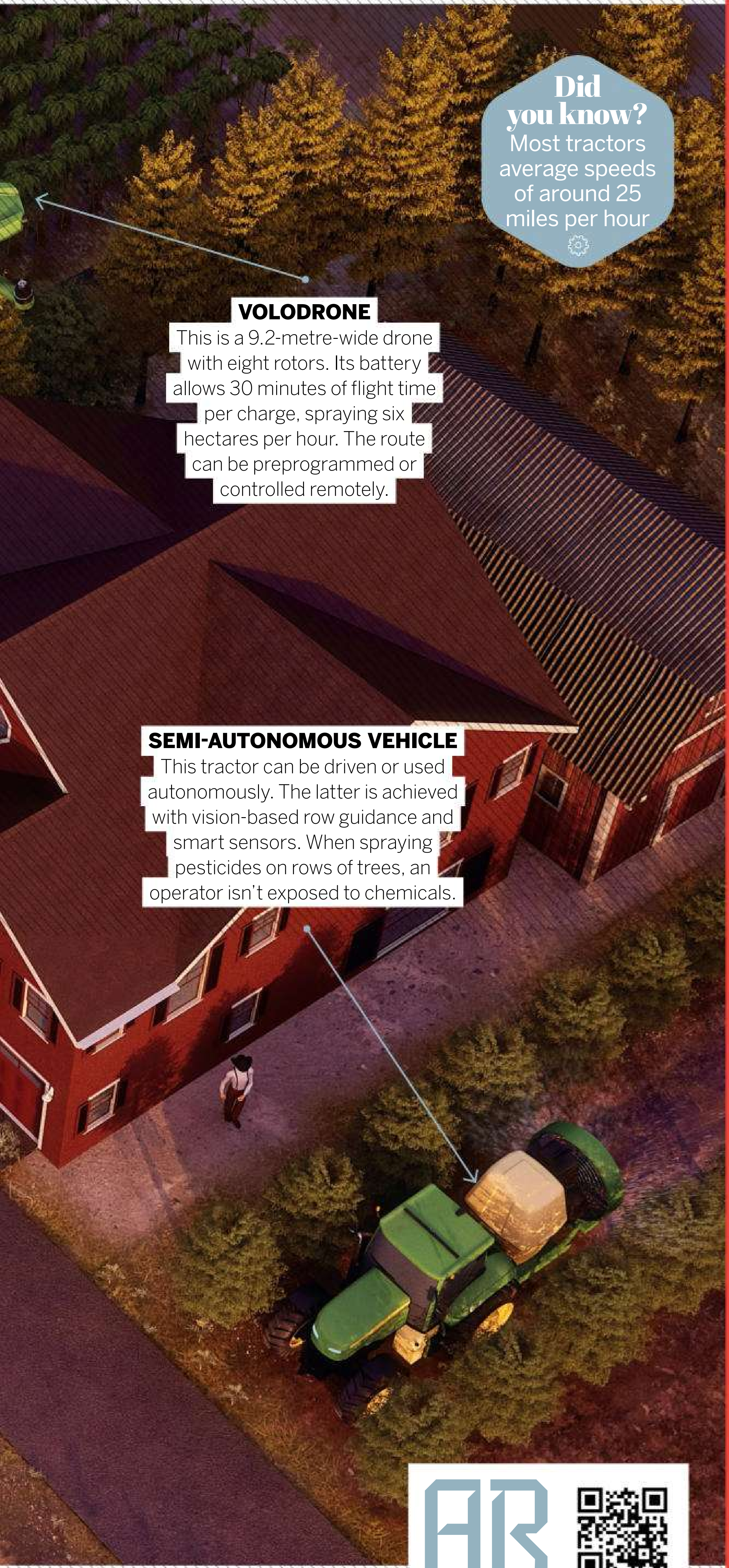
SEE & SPRAY
Smart camera technology can detect different colouration as it scans fields. Water is targeted at green crops, limiting any water that is wasted on the surrounding land.

CONNECTED TECHNOLOGY
A smart device such as a tablet – or built-in technology inside a driven tractor – can be used to track the progress and live location of the farm's operating tractors. This helps when monitoring vehicles with no driver.

EFFICIENT HARVESTING
OMNiDRIVE is new technology that can turn grain-collecting vehicles into autonomous ones. Instead of requiring two drivers, the grain cart can be programmed to follow the combine harvester and automatically match its speed.

> "Tractors are evolving as new tools expand the boundaries of farming"

DID YOU KNOW? Monarch Tractor released the world's first fully electric and autonomous tractor in 2020



Did you know? Most tractors average speeds of around 25 miles per hour

VOLODRONE

This is a 9.2-metre-wide drone with eight rotors. Its battery allows 30 minutes of flight time per charge, spraying six hectares per hour. The route can be preprogrammed or controlled remotely.

SEMI-AUTONOMOUS VEHICLE

This tractor can be driven or used autonomously. The latter is achieved with vision-based row guidance and smart sensors. When spraying pesticides on rows of trees, an operator isn't exposed to chemicals.

AR zone

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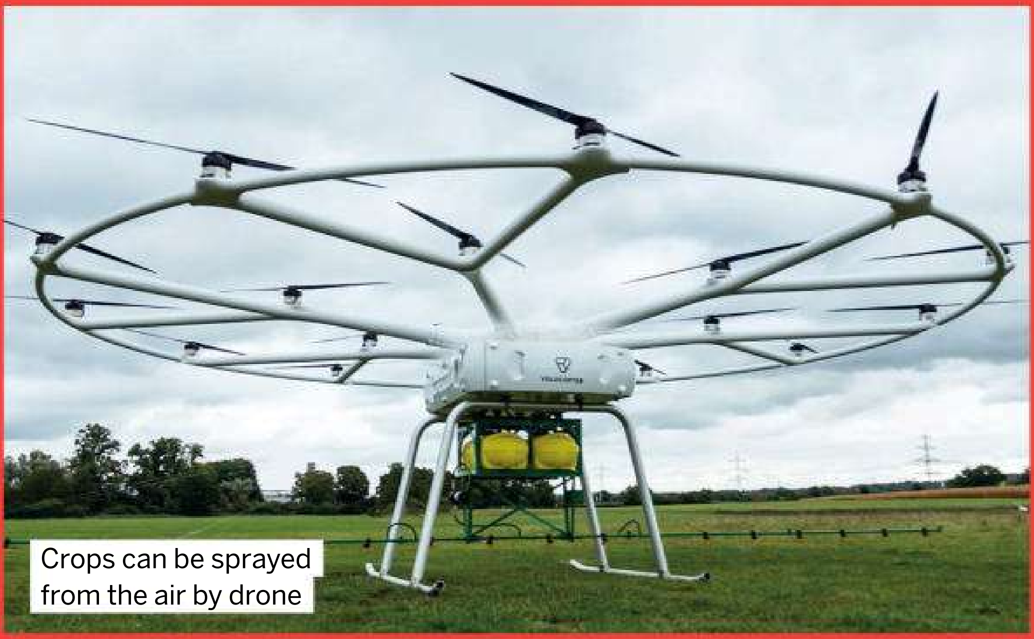
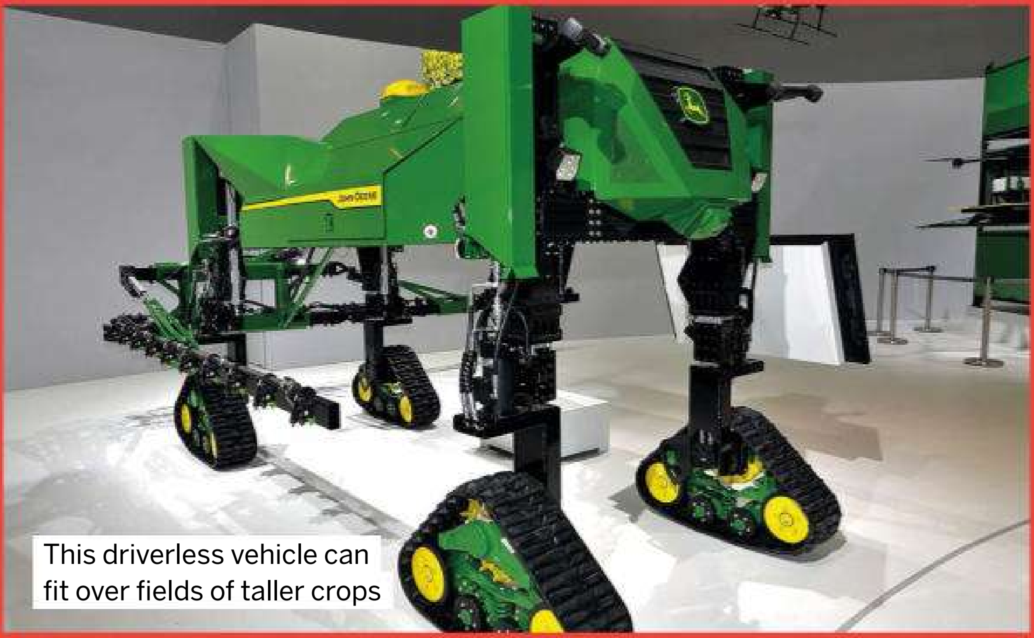
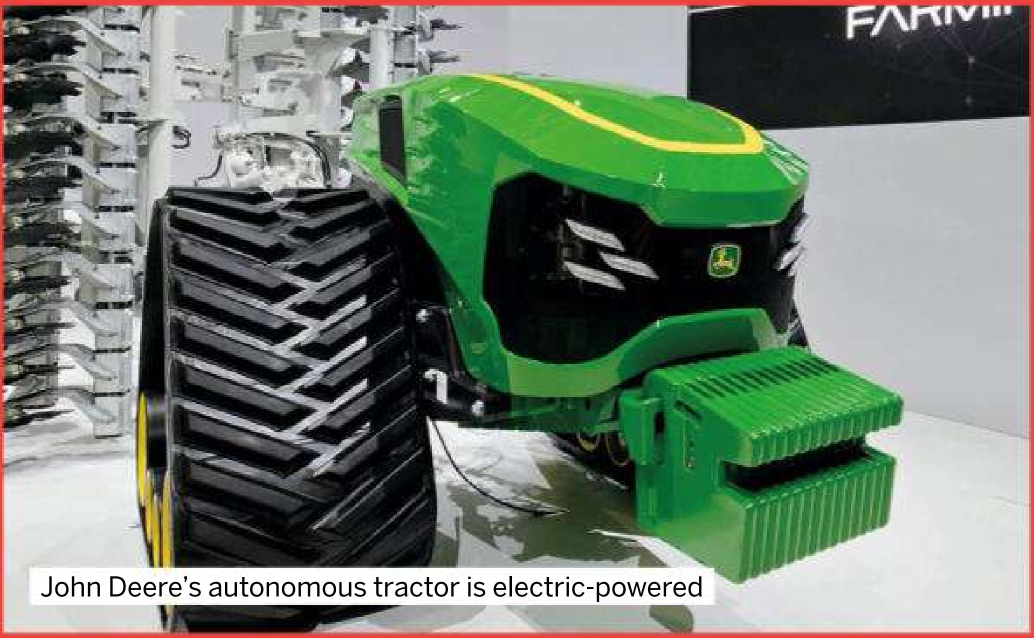


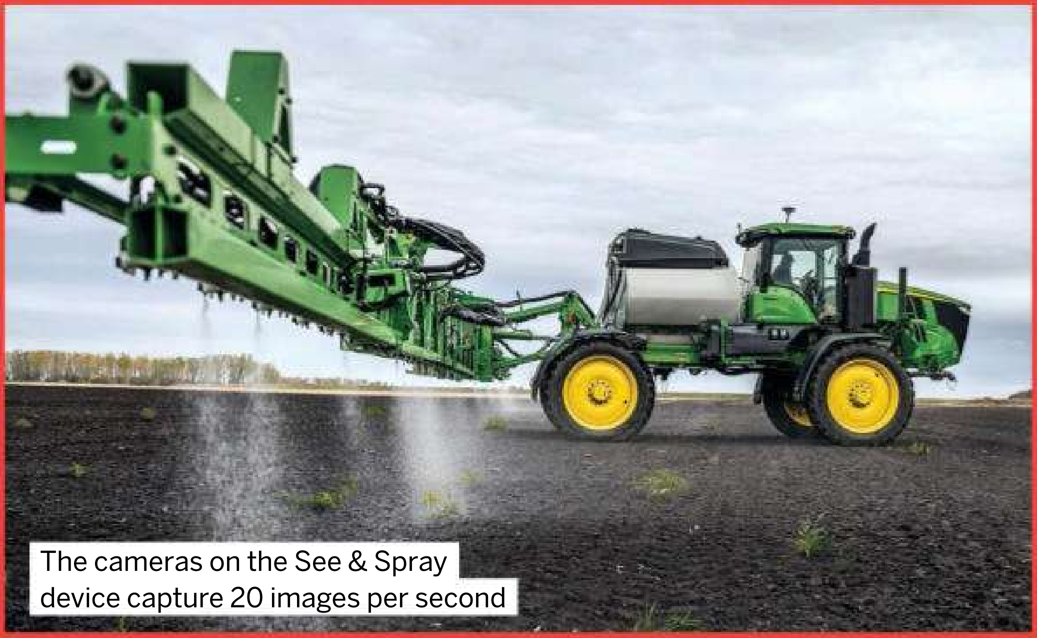
Crops can be sprayed from the air by drone



This driverless vehicle can fit over fields of taller crops



John Deere's autonomous tractor is electric-powered



The cameras on the See & Spray device capture 20 images per second

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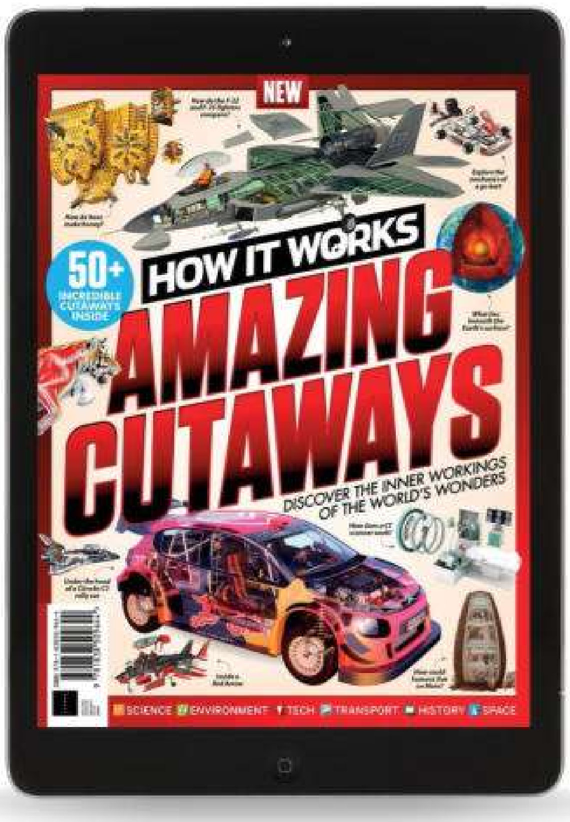

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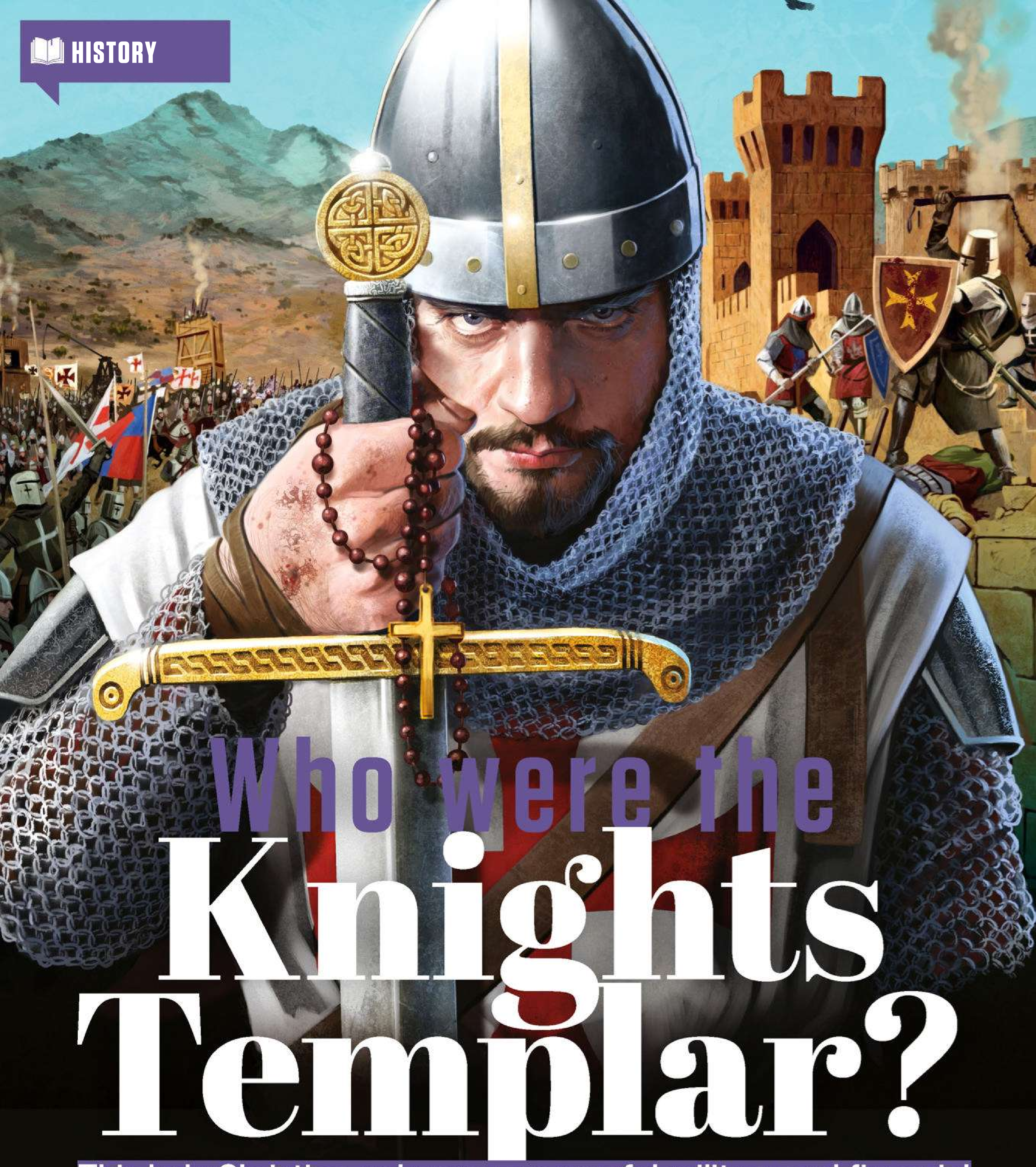


Who were the Knights Templar?

This holy Christian order was a powerful military and financial group for over two centuries

WORDS **MARTYN CONTERIO**

DID YOU KNOW? Templar knights wore the distinctive red cross, while sergeants wore plain clothes

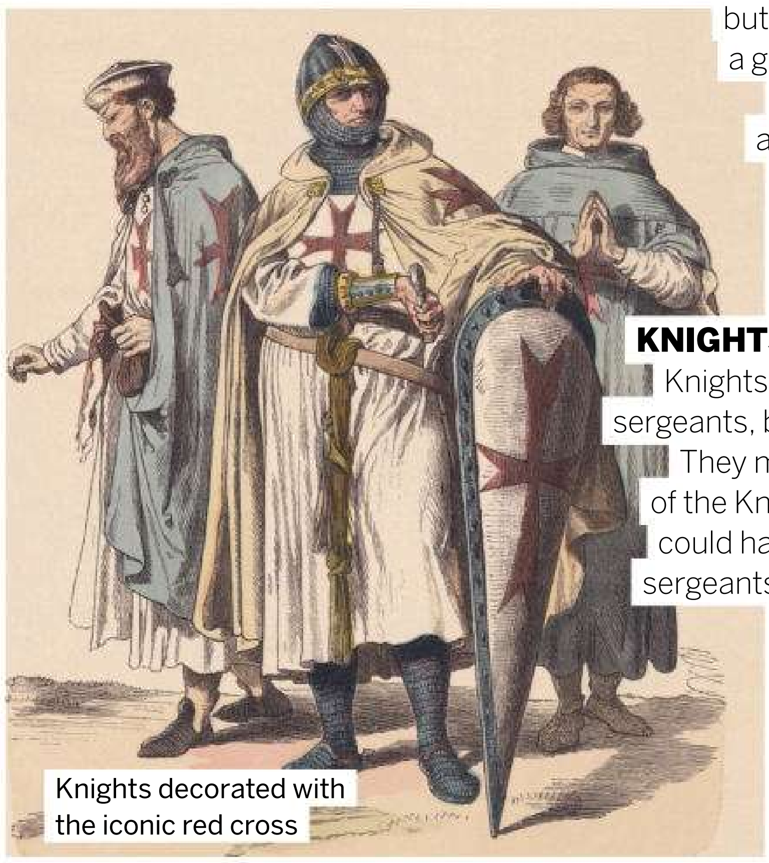
The Knights Templar was an order of devout Catholics founded in Jerusalem in 1118 CE, after the First Crusade. Also known as the Order of Solomon's Temple, it was created to protect Europeans travelling to the Holy Land, among other duties. The knights were known across Europe as an elite fighting force with a strict code of conduct and, eventually, immense wealth. For nearly 200 years the Knights Templar were at the centre of politics and finance in Europe, taking part in Christian military campaigns in the Holy Land.

In the seventh century, a Muslim Arab army conquered Jerusalem and the Holy Land, ending Christian rule in the region under the Byzantine Empire, also called the Eastern Roman Empire. By the end of the 11th century, the Byzantine Empire had lost more territory to Muslim invasions, including more Christian holy sites. In response, the pope called for the capture of Christianity's holy sites in the Holy Land, beginning the First Crusade in 1096.

A multinational army was raised for the Crusade, led by several of Europe's monarchs and nobility. The Crusaders succeeded in capturing not only Jerusalem, but also much of the region. They created four territories, known as Crusader States: the County of Edessa, the Principality of Antioch, the County of Tripoli and the Kingdom of Jerusalem. These states were also known as Outremer, meaning 'overseas', from the French term outré-mer.

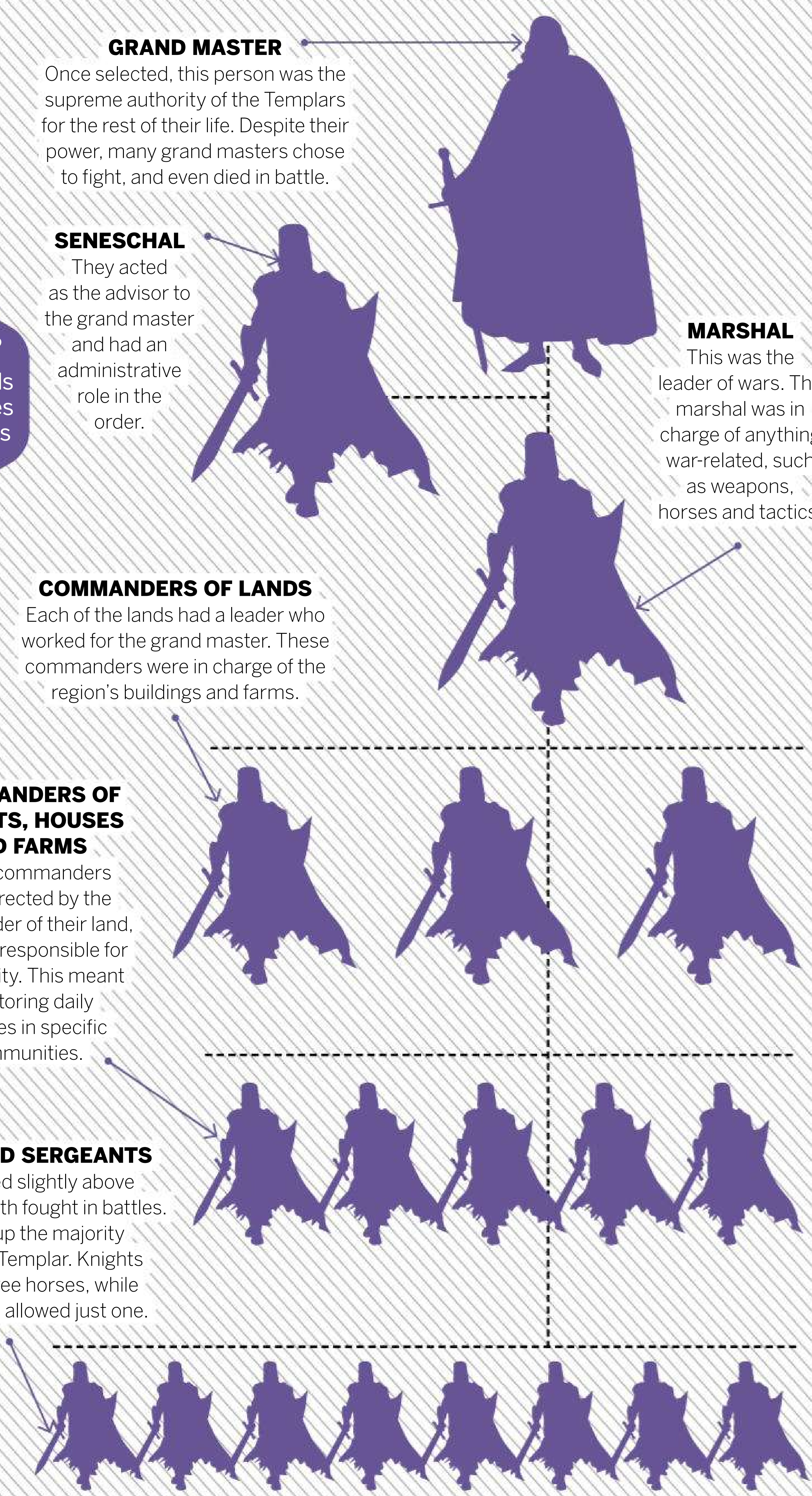
After most of the Crusaders returned to Europe, there remained a need to defend the Holy Land, as well as govern its population, which included Christians, Jews, Muslims and new settlers from Europe. They needed to consolidate their hold on Jerusalem and the immediate vicinity. But they didn't really have a consolidated state that would form a solid area on a map. Another problem they had is that a certain number of places they controlled were very easy for an enemy to infiltrate, and there was nothing really to keep law and order. It was these circumstances that produced the Templars.

Did you know?
European royals donated estates to the Templars


Knights decorated with the iconic red cross

TEMPLAR HIERARCHY

They were all known as knights, but their varied roles provided structure



GRAND MASTER
Once selected, this person was the supreme authority of the Templars for the rest of their life. Despite their power, many grand masters chose to fight, and even died in battle.

SENESCHAL
They acted as the advisor to the grand master and had an administrative role in the order.

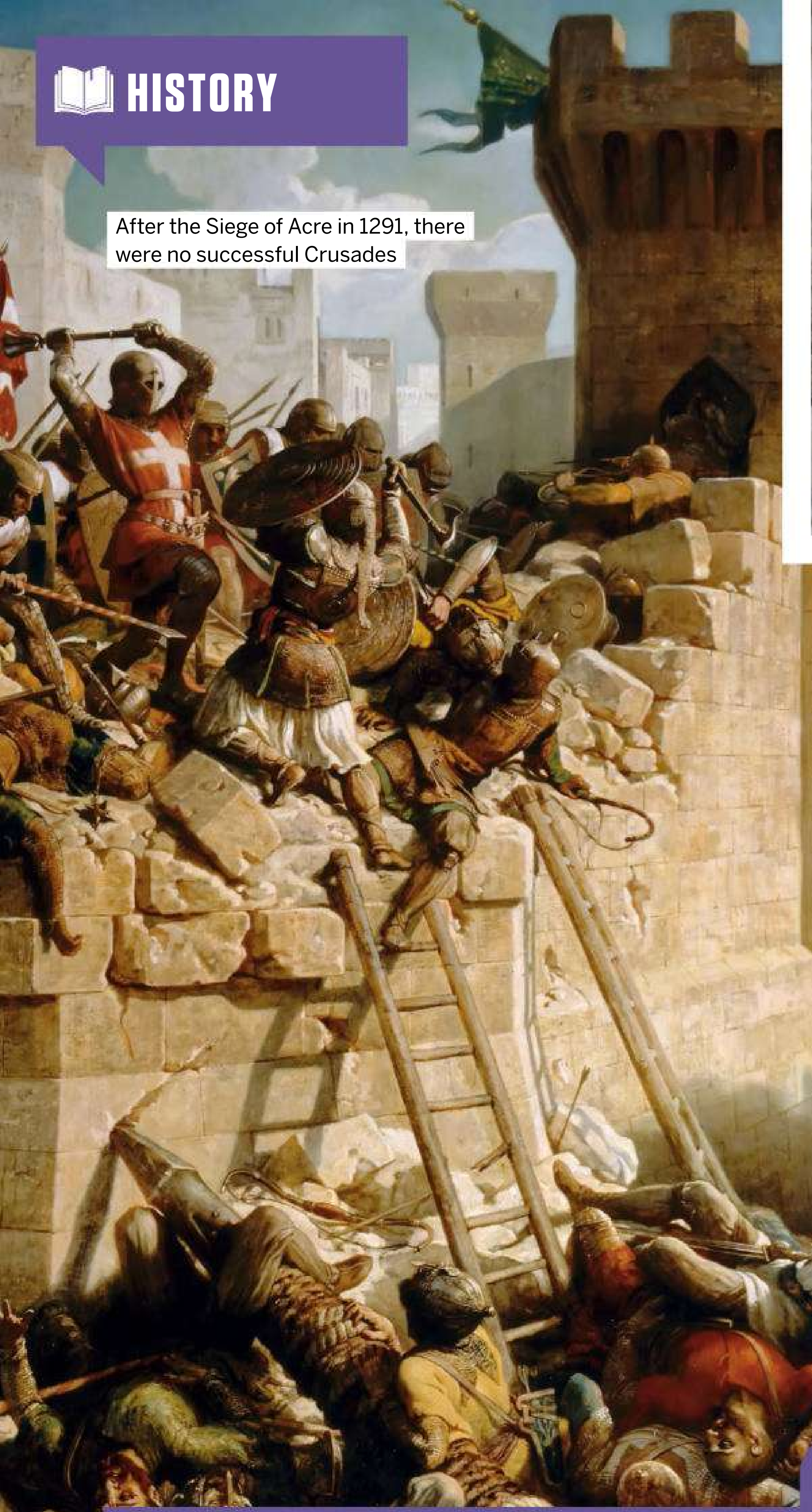
MARSHAL
This was the leader of wars. The marshal was in charge of anything war-related, such as weapons, horses and tactics.

COMMANDERS OF LANDS
Each of the lands had a leader who worked for the grand master. These commanders were in charge of the region's buildings and farms.

COMMANDERS OF KNIGHTS, HOUSES AND FARMS
These commanders were directed by the commander of their land, but were responsible for a given city. This meant monitoring daily activities in specific communities.

KNIGHTS AND SERGEANTS
Knights ranked slightly above sergeants, but both fought in battles. They made up the majority of the Knights Templar. Knights could have three horses, while sergeants were allowed just one.

© Getty



After the Siege of Acre in 1291, there were no successful Crusades

This Templar tombstone was discovered in Cyprus

END OF THE ORDER

Once the Crusades were over and Muslim forces controlled Jerusalem, military orders, including the Templars, were blamed for the loss of the Holy Land. After the Mamluks conquered the city of Acre in 1291, the Templars and other orders retreated to the island of Cyprus.

This prompted demands to reform the military orders. Philip IV of France, who was in huge financial debt to the Templars, ordered the mass arrest of French Templars on 13 October 1307, confiscating their property and wealth.

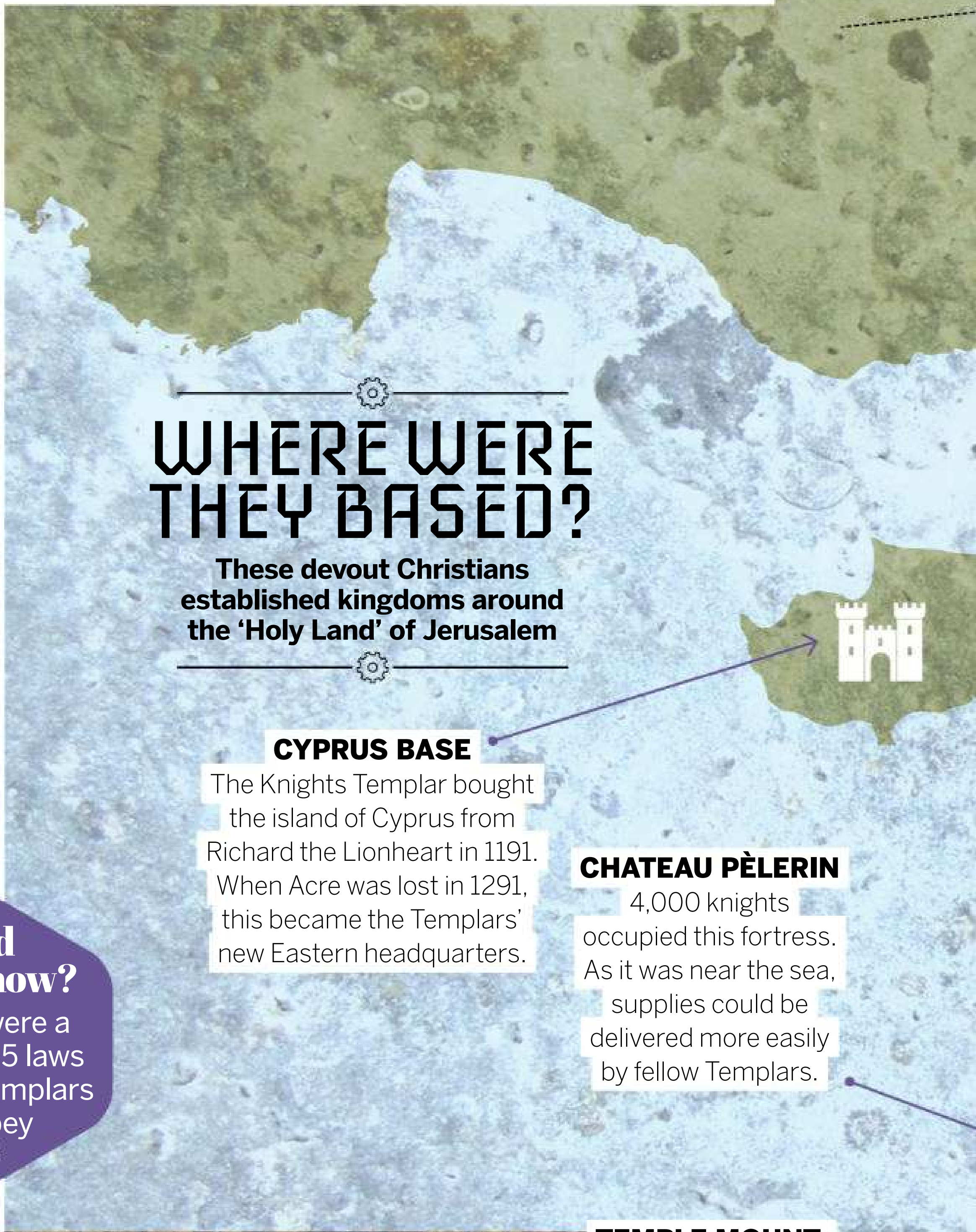
Prosecutors charged the Templars with worshipping idols, spitting on the cross and kissing one another in their induction ceremonies. Under torture, the Templars confessed to the charges. In 1308, Pope Clement V absolved the Templars of heresy, but the order and its reputation had already been damaged. In March 1312, Pope Clement V disbanded the Templars as an organisation, and the order's members were arrested across Europe. Two years later, Jacques de Molay, the last grand master, was burned at the stake in Paris on a charge of relapsed heresy.

Did you know?

There were a total of 25 laws for the Templars to obey

WHERE WERE THEY BASED?

These devout Christians established kingdoms around the 'Holy Land' of Jerusalem



CYPRUS BASE

The Knights Templar bought the island of Cyprus from Richard the Lionheart in 1191. When Acre was lost in 1291, this became the Templars' new Eastern headquarters.

CHATEAU PÈLERIN

4,000 knights occupied this fortress. As it was near the sea, supplies could be delivered more easily by fellow Templars.

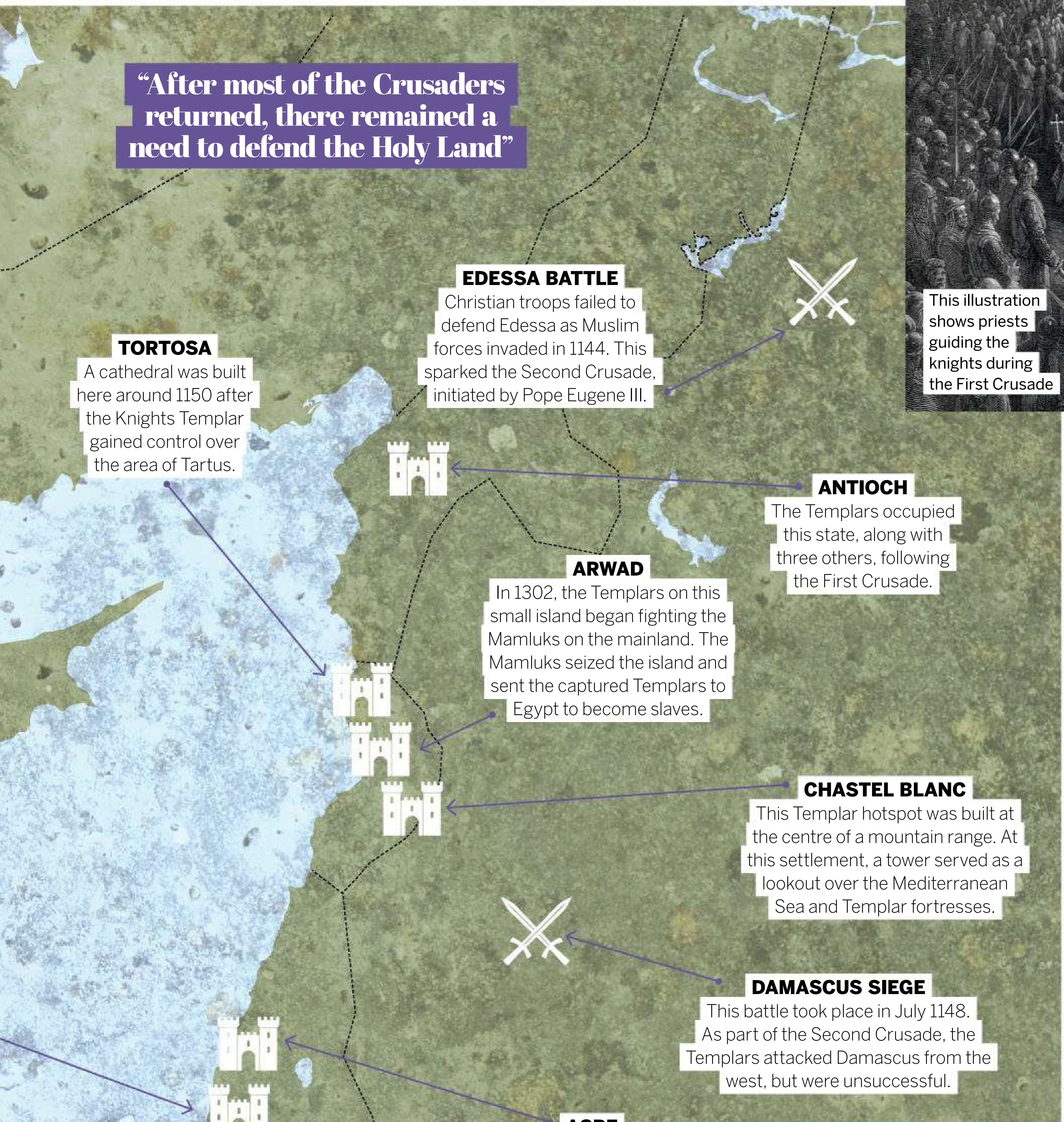
TEMPLE MOUNT, JERUSALEM

This was the first headquarters used in Jerusalem as the Templars defended the city.

The southeast corner of Temple Mount

DID YOU KNOW? The knights were known as 'milites Christi', meaning 'Christ's soldiers'

> "After most of the Crusaders returned, there remained a need to defend the Holy Land"



EDESSA BATTLE
Christian troops failed to defend Edessa as Muslim forces invaded in 1144. This sparked the Second Crusade, initiated by Pope Eugene III.

TORTOSA
A cathedral was built here around 1150 after the Knights Templar gained control over the area of Tartus.

ANTIOCH
The Templars occupied this state, along with three others, following the First Crusade.

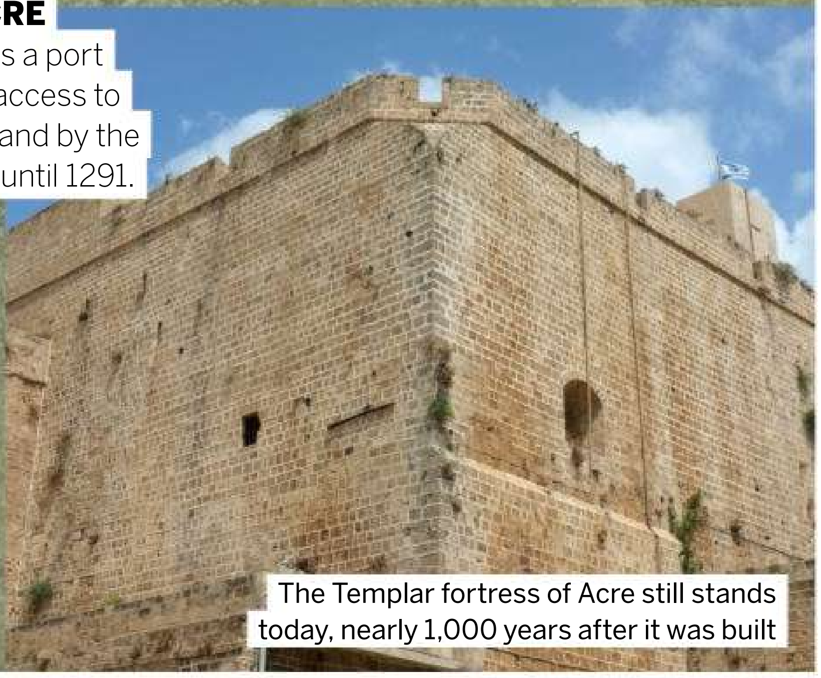
ARWAD
In 1302, the Templars on this small island began fighting the Mamluks on the mainland. The Mamluks seized the island and sent the captured Templars to Egypt to become slaves.

CHASTEL BLANC
This Templar hotspot was built at the centre of a mountain range. At this settlement, a tower served as a lookout over the Mediterranean Sea and Templar fortresses.

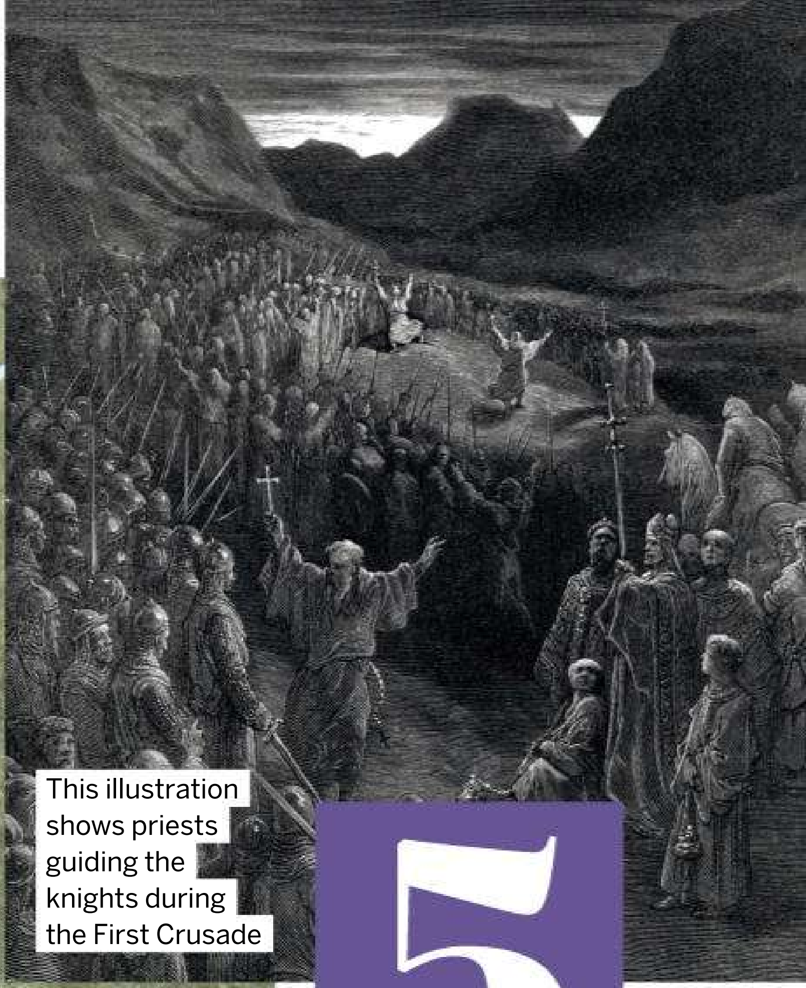
DAMASCUS SIEGE
This battle took place in July 1148. As part of the Second Crusade, the Templars attacked Damascus from the west, but were unsuccessful.

ACRE
This was a port used as access to the Holy Land by the Templars until 1291.

MALDOIM
This base was used to defend the road between Jerusalem and Jericho.



The Templar fortress of Acre still stands today, nearly 1,000 years after it was built



This illustration shows priests guiding the knights during the First Crusade

5 TEMPLAR RULES

1 ALWAYS OBEY ORDERS
Accepting absolute obedience meant that knights acted quickly once commanded, creating a strong unit.

2 NO FANCY CLOTHES
The Templars' uniforms were plain, with a red cross on the chest. Fur clothes and pointed shoes were banned.

3 EAT IN PAIRS
The knights carried out many activities in pairs. This was practical as it meant each knight was closely observed. Meals were eaten in silence.

4 DON'T SAVE MONEY
Money couldn't be carried unless permission was given. The Templars had to swear an oath of poverty in order to fully commit to god.

5 NEVER DESERT THE LINE
This rule heightened control on the battlefield and helped to maintain formation. The knights were expected to fight until the end, follow orders and only act with permission.

© Getty

Maya cities lie in ruin today, visited by many tourists

DID YOU KNOW? The earliest Maya spoke one language. Today there are around 70 Mayan languages still in use

WHY THE Maya CIVILISATION COLLAPSED

What went wrong for this ancient South American nation?

WORDS **OWEN JARUS**

The Maya have lived in Central America and the Yucatán Peninsula since at least 1800 BCE, flourishing in the region for thousands of years. The Maya civilisation collapsed between 800 and 1000 CE. But though the term 'Maya collapse' brings up images of ruins overgrown with forests and of an ancient civilisation whose cities fell and were abandoned, the reality is far more complex.

Just why did the Maya civilisation collapse, and can you even call it a 'collapse'? For starters, the Maya are still around today. It was the Maya political system that collapsed, not their society. The Maya region was large, with many environments, and multiple languages were spoken in the Maya family.

When the city of Chichén Itzá declined – largely because of a lengthy drought during the 11th century – another Yucatán Peninsula city called Mayapán started to thrive. Mayapán had lords, priests, hundreds of religious hieroglyphic books, complex astronomy and a pantheon of deities. Much of what we know about earlier Maya religion comes from books written in Mayapán's day and from descendant populations who met and survived European contact.

While Mayapán declined prior to European contact, another Yucatán Peninsula site called Ti'ho was growing at the time the Europeans arrived. Maya states continued to exist even after the region was ravaged by war and disease brought about by the European conquests in Central America.

Did you know?
Prisoners of war played 'ulama', with losers put to death

MODERN MAYA

After the last Maya state was conquered by the Spanish in 1697, the Maya people continued on, enduring discrimination and at times revolting against Spain and the governments that came into power after Spanish colonial rule ended in 1821. This arrival brought about a profound change in the Maya world. New diseases decimated the Maya, and the Spaniards forced the Maya to convert to Christianity, even burning their books.

Today, despite the devastation they experienced, the Maya people live on. Although classic Maya cities and states did collapse, and culture did transform, the Maya didn't disappear. The descendant population of over 7 million in Mesoamerica now lacks adequate political representation in the countries where they live.

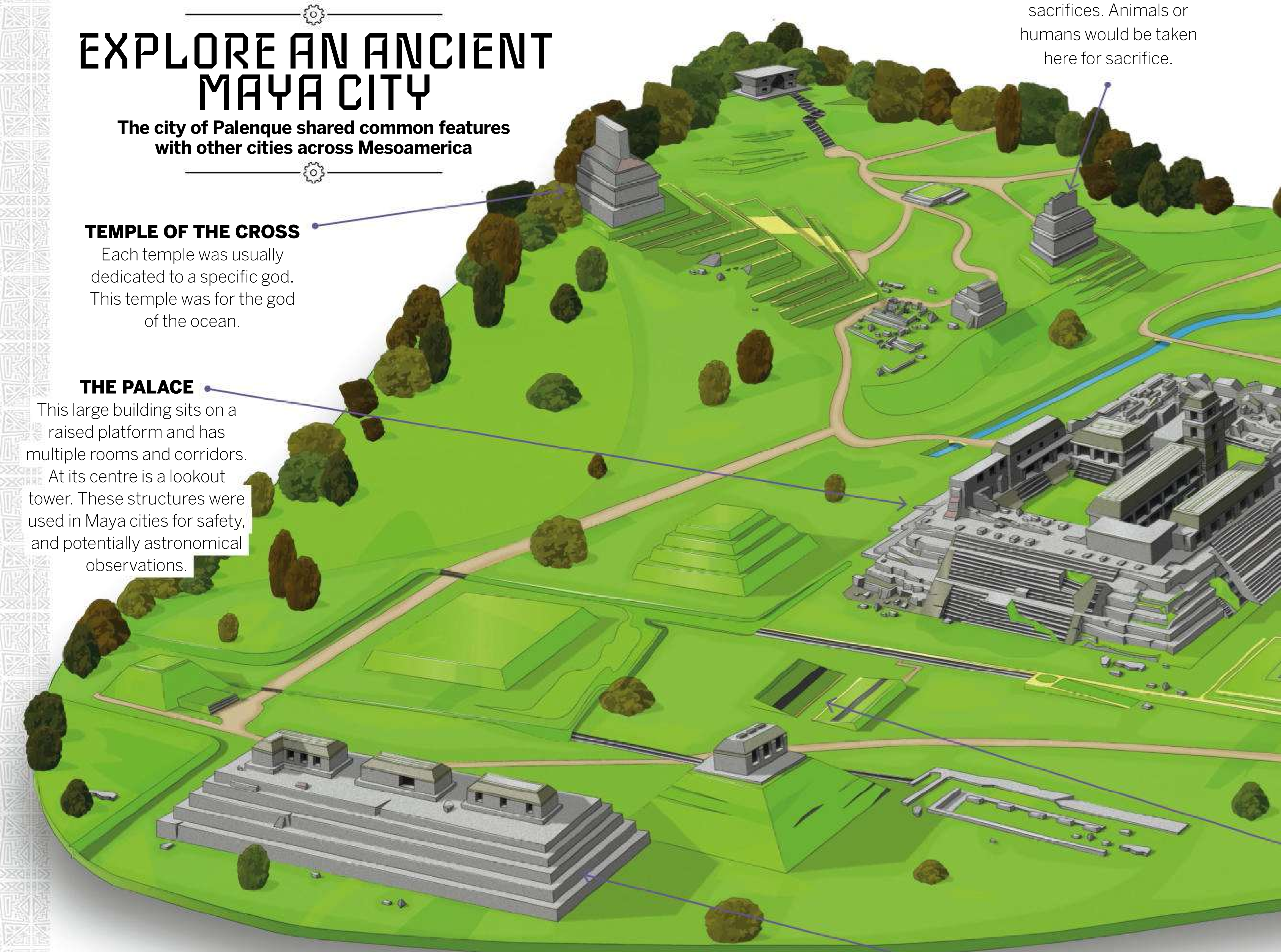
In Guatemala, Maya descendents make up over 40 per cent of the population

This 14th-century manuscript displays ancient Mayan symbols

© Alamy / Getty

EXPLORE AN ANCIENT MAYA CITY

The city of Palenque shared common features with other cities across Mesoamerica



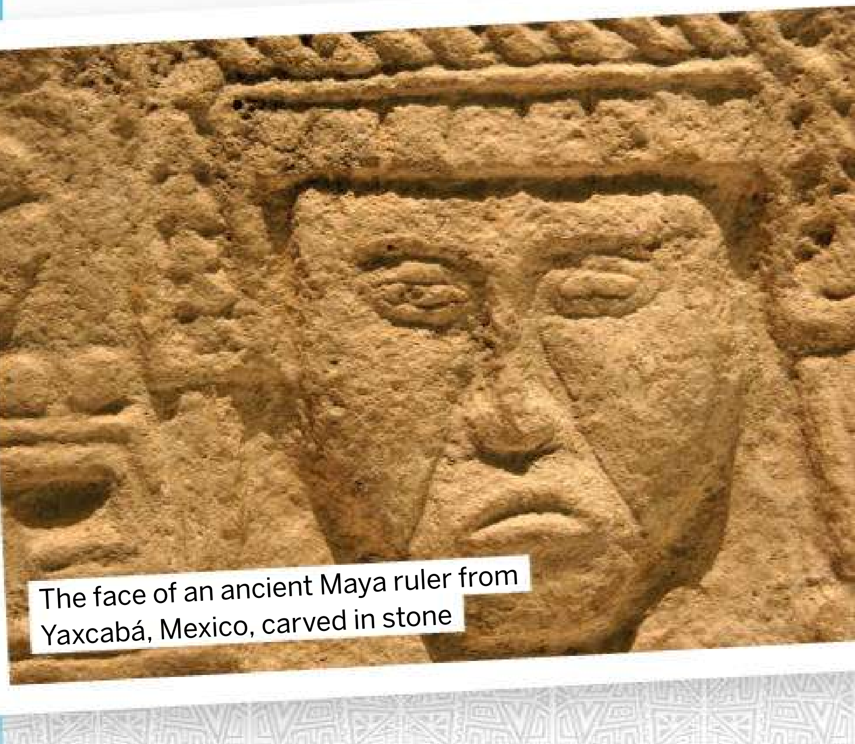
TEMPLE OF THE SUN
Ancient Maya civilisations believed that the Sun wouldn't travel across the sky unless they made sacrifices. Animals or humans would be taken here for sacrifice.

TEMPLE OF THE CROSS
Each temple was usually dedicated to a specific god. This temple was for the god of the ocean.

THE PALACE
This large building sits on a raised platform and has multiple rooms and corridors. At its centre is a lookout tower. These structures were used in Maya cities for safety, and potentially astronomical observations.

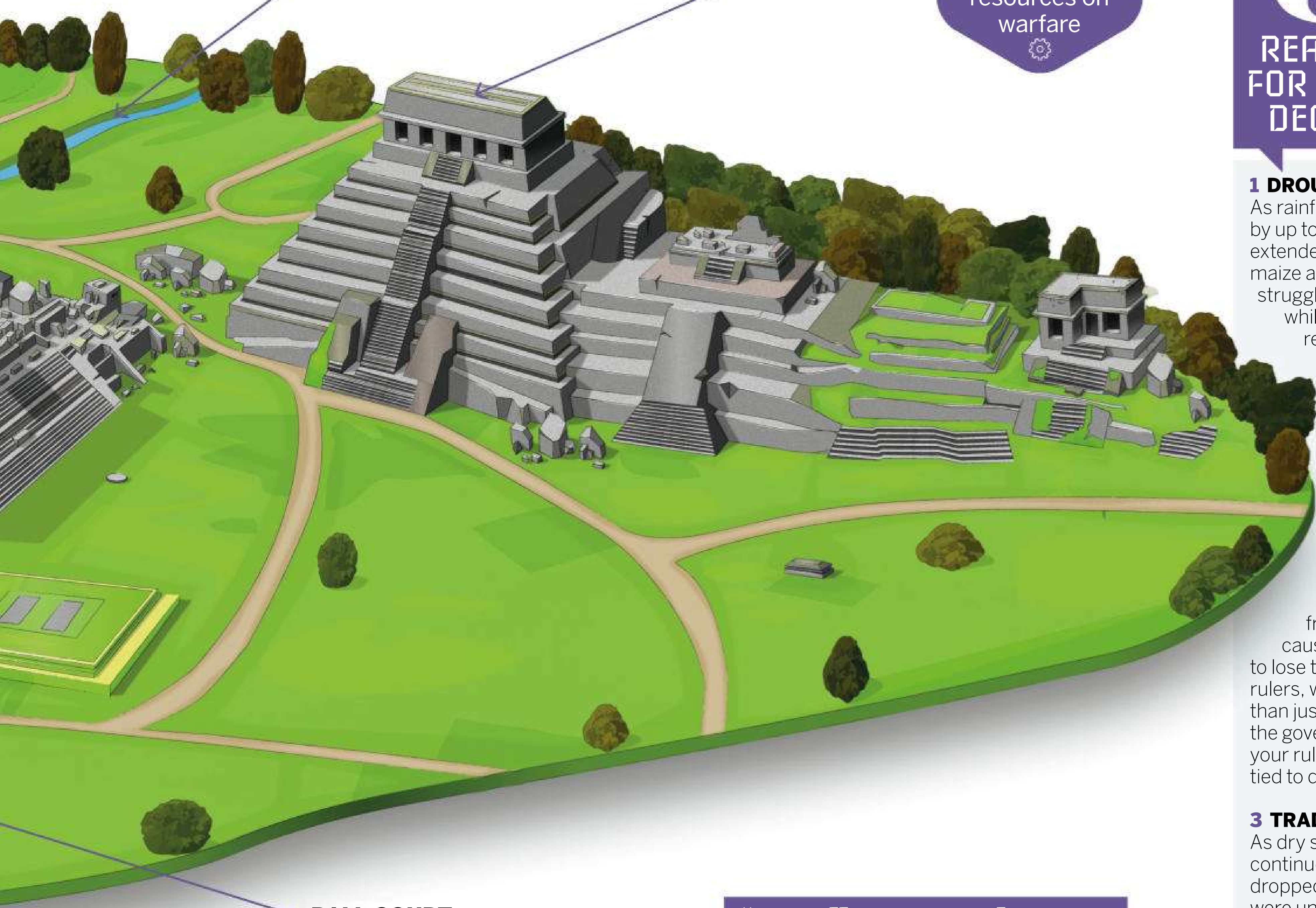
NORTHERN GROUP
More temples can be found north of the city's centre. Maya temples were made from stone.

The aim of the ancient Maya ball game 'ulama' was to get the balls through stone rings



The face of an ancient Maya ruler from Yaxcabá, Mexico, carved in stone

DID YOU KNOW? There was an abundance of soft limestone around the city of Palenque, which was used for carving



SACRED RIVER
The Otolum river runs south of the palace. Palenque's ancient occupants called the city 'Lakamha', meaning 'place of great water'.

TEMPLE OF THE INSCRIPTIONS
King Pakal ruled Palenque for 68 years – the longest of any ancient Maya leader. When he died in 683 CE, his body was buried here.

Did you know?
Some Maya rulers wasted resources on warfare

BALL COURT
Ulama was a popular ball game played by Maya across Mesoamerica. The game involved keeping the ball off the ground without using hands or feet.

> "Not all Maya settlements were controlled by a king or an elite member of society."

5 REASONS FOR CITIES' DECLINE

1 DROUGHT
As rainfall decreased by up to 70 per cent for extended periods, maize and other crops struggled to grow, while drinking reservoirs became empty.

2 TRUST
Maya rulers often linked their own power to deities. The problems the Maya suffered from droughts caused the people to lose trust in their rulers, which is more than just losing trust in the government when your rulers are closely tied to deities.

3 TRADING
As dry seasons continued, river levels dropped until canoes were unable to travel along them. This impacted the trade of goods between cities.

4 POPULATION
The overpopulation of Maya cities may have put a bigger strain on resources. As more land was cleared for the growing population, the region's ecosystem was also challenged.

5 INCREASED WARFARE
As archaeologists have studied Maya history, they've learned that these cities engaged in several violent wars. Hostility between large cities may have grown as resources became less available.

ANCIENT LEADERS

The ancient Maya didn't have one central leader – like an emperor in ancient Rome – and were not unified into a single state. Instead, the ancient Maya civilisation consisted of numerous small states, each centred around a city. While these city-states shared similarities in culture and religion, they each had their own local leaders, with some more powerful than others.

Not all Maya settlements were controlled by a king or an elite member of society. At Joya de Cerén, a Maya village in El Salvador that was buried by a volcanic eruption 1,400 years ago, archaeologists found that there was no elite class in control, and the village seems to have been managed communally, perhaps by local elders.

There was no single collapse for these polities; a number of Maya cities rose and fell at different times, some within the 800 to 1000 CE time period, and some afterward. For example, while areas in southern Mesoamerica – a cultural region that forms the southern tip of continental North America – such as Tikal in what is now Guatemala, declined in the eighth and ninth centuries due to environmental problems and political turmoil, populations rose in other areas, such as Chichén Itzá on what is now the Mexican Yucatán Peninsula.

© Alamy / Getty / Illustration by The Art Agency; Nick Sellers

INSIDE BATH'S ROYAL CRESCENT

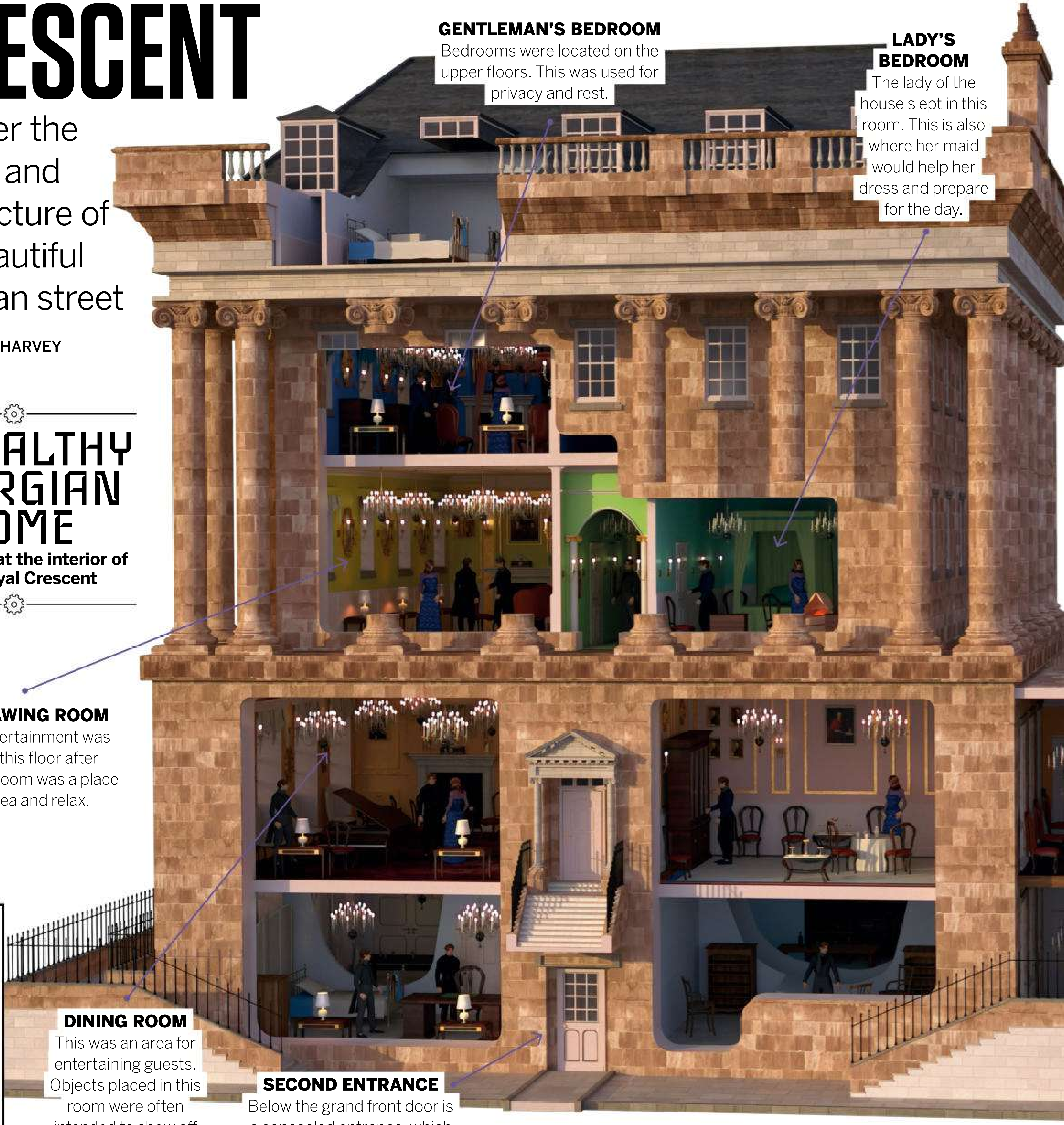
Discover the history and architecture of this beautiful Georgian street

WORDS **AILSA HARVEY**

The curved row is very striking

A WEALTHY GEORGIAN HOME

Take a look at the interior of No. 1 Royal Crescent



GENTLEMAN'S BEDROOM
Bedrooms were located on the upper floors. This was used for privacy and rest.

LADY'S BEDROOM
The lady of the house slept in this room. This is also where her maid would help her dress and prepare for the day.

WITHDRAWING ROOM
Evening entertainment was moved to this floor after dinner. This room was a place to drink tea and relax.

DINING ROOM
This was an area for entertaining guests. Objects placed in this room were often intended to show off the owner's wealth.

SECOND ENTRANCE
Below the grand front door is a concealed entrance, which servants were restricted to.

AR zone

SCAN HERE

DID YOU KNOW? In Charles Dickens' *The Pickwick Papers*, Mr Pickwick stays in the Royal Crescent

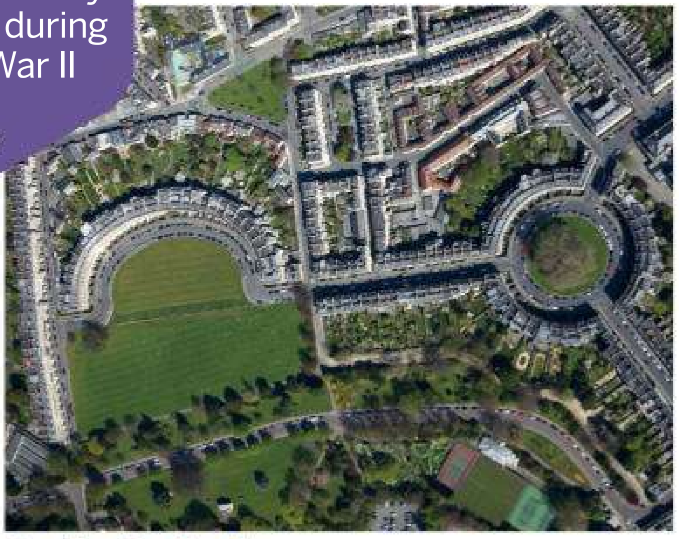
The city of Bath in Somerset, England, is famous for its golden stone buildings, quaint cobbled streets and Roman baths. While Bath became a spa when the Romans built the baths in 60 CE, its popularity only surged as a spa town during the Georgian era. During this time, many of Bath's picturesque buildings were built, including the Royal Crescent.

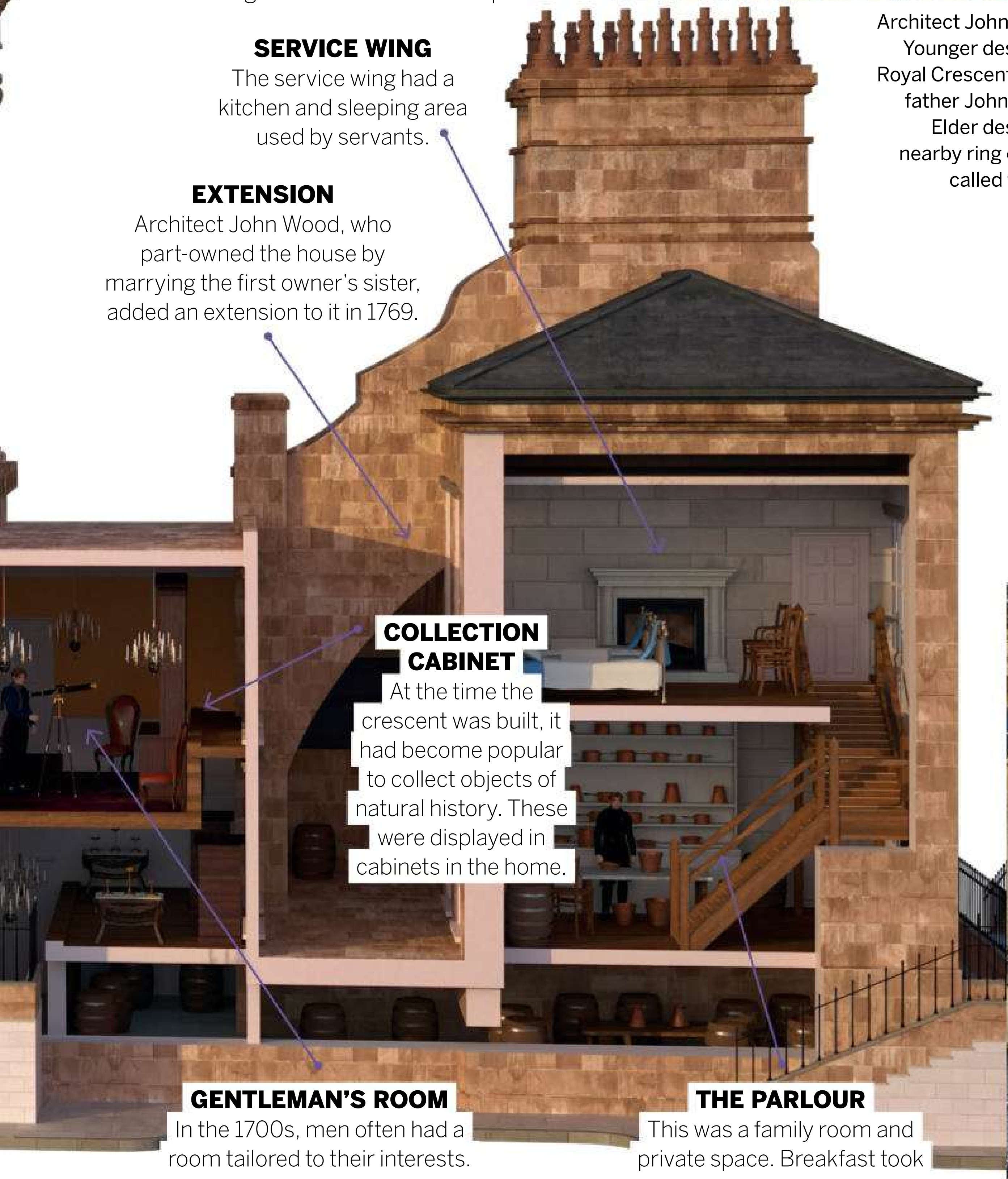
This curved row of 30 terraced houses was designed by architect John Wood the Younger and built between 1767 and 1774. These homes were targeted at middle-class city residents. Although they didn't have the money to afford a large mansion in the countryside, the new residents wanted to live in a luxurious city dwelling. The original owners were allowed to personalise the interior build of their new homes, meaning that no two houses in this sweeping crescent have an identical layout.

The Royal Crescent is over 150 metres long and is adorned with 114 tall columns – a classic feature of Georgian architecture. In the space in front of the crescent's houses is a large lawn, designed to be an open space for the residents to enjoy.

This grassy area previously held grazing livestock and was used to grow food when it was limited during World War II. A fence and ditch – called a ha-ha – separates this private section of grass from Royal Victoria Park. This also helped to keep livestock out of the formal garden.

Did you know?
No. 2 was hit by bombers during World War II


Architect John Wood the Younger designed the Royal Crescent, while his father John Wood the Elder designed the nearby ring of houses, called the Circus


SERVICE WING
The service wing had a kitchen and sleeping area used by servants.

EXTENSION
Architect John Wood, who part-owned the house by marrying the first owner's sister, added an extension to it in 1769.

COLLECTION CABINET
At the time the crescent was built, it had become popular to collect objects of natural history. These were displayed in cabinets in the home.

GENTLEMAN'S ROOM
In the 1700s, men often had a room tailored to their interests. There they could read or work.

THE PARLOUR
This was a family room and private space. Breakfast took place here as an informal meal.

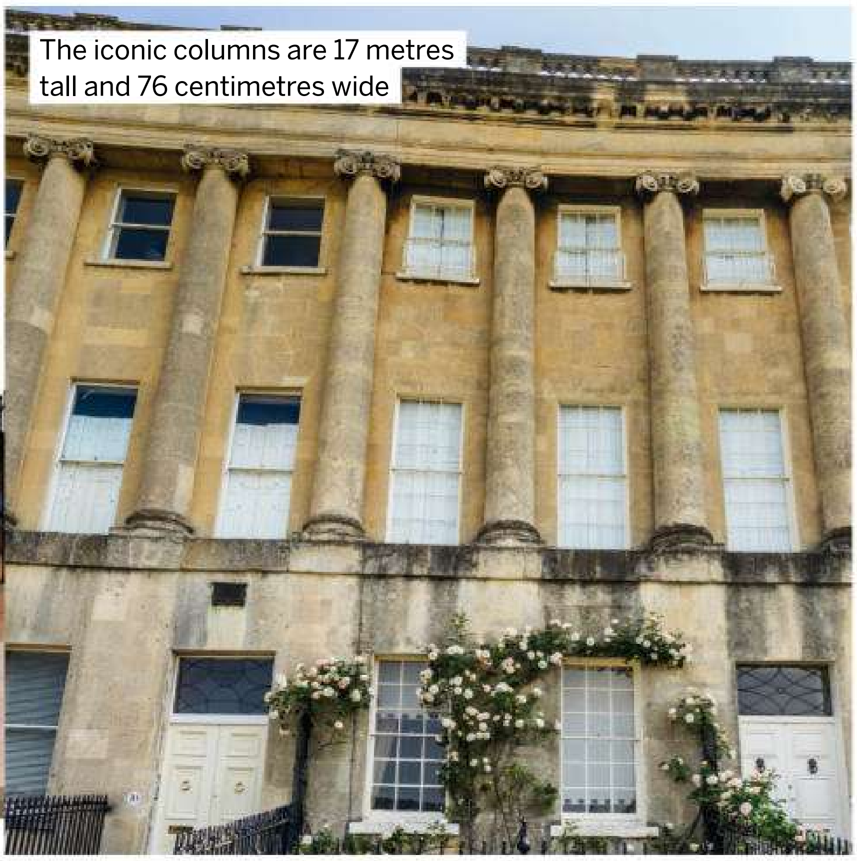
The majority of Georgian buildings in Bath are made from the same stone

BUILDING WITH BATH STONE

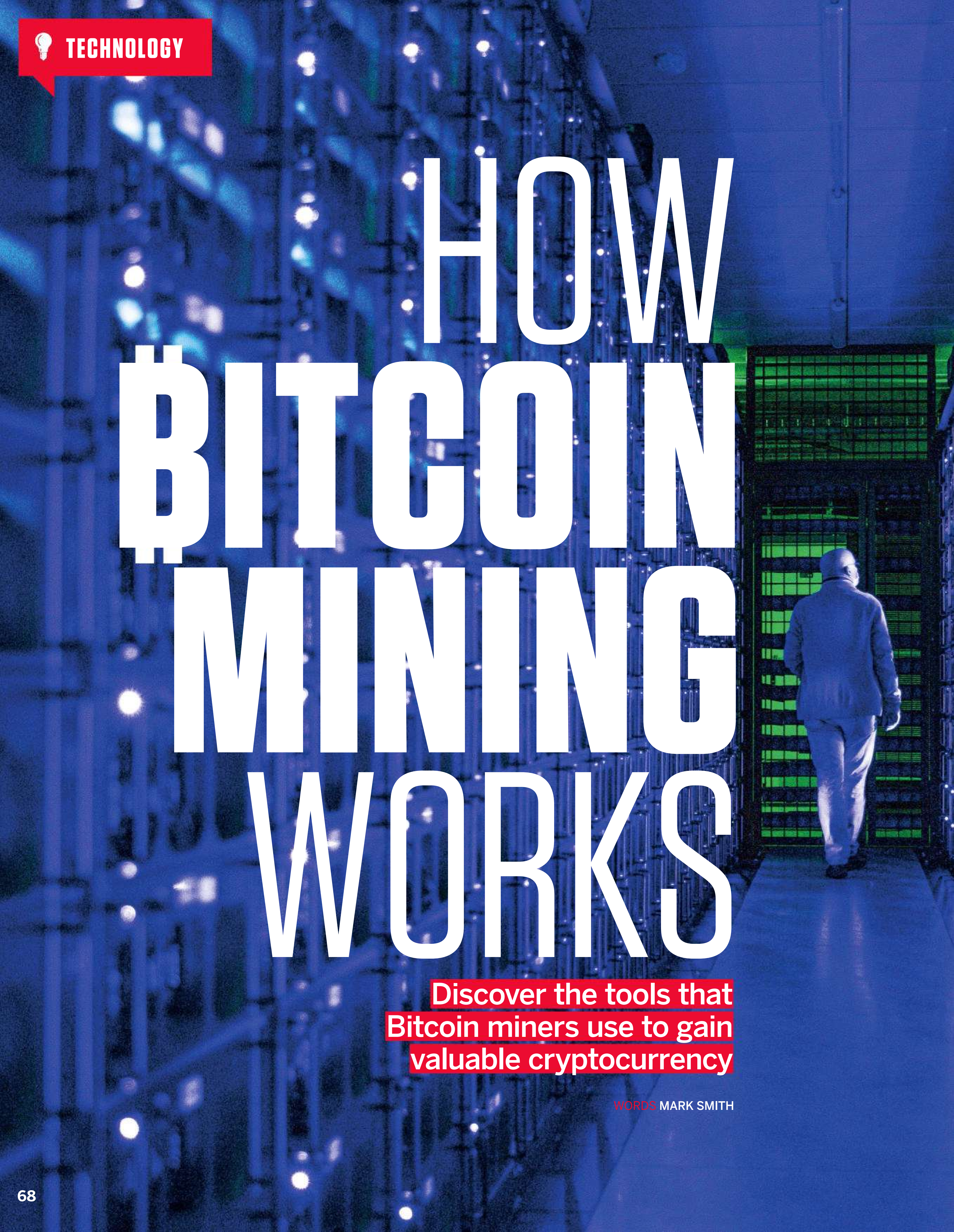
The honey-coloured stone that makes up the Royal Crescent is known as 'Bath stone'. In the Jurassic Period, which ran from 201 to 145 million years ago, the land that Bath sits on was underwater. As calcium carbonate grains moved across the seafloor, they combined with the inorganic mineral lime. Sediment continued to fall in layers, putting pressure on the rock and producing limestone.

This made the perfect building material for the Royal Crescent and many other buildings in Bath, because it's a freestone: it formed from tiny grains of minerals and rock, so the stone can be cut easily in any direction without it breaking into distinct layers like other rocks.

Architect John Wood worked with entrepreneur Ralph Allen to source and utilise the stone from Combe Down, on the outskirts of Bath. This is where large amounts of Bath stone was extracted during the Georgian era. Allen owned these quarries and built a tramway to transport the stone to the crescent.


The iconic columns are 17 metres tall and 76 centimetres wide

© Alamy / Getty / Illustration by Nicholas Forder



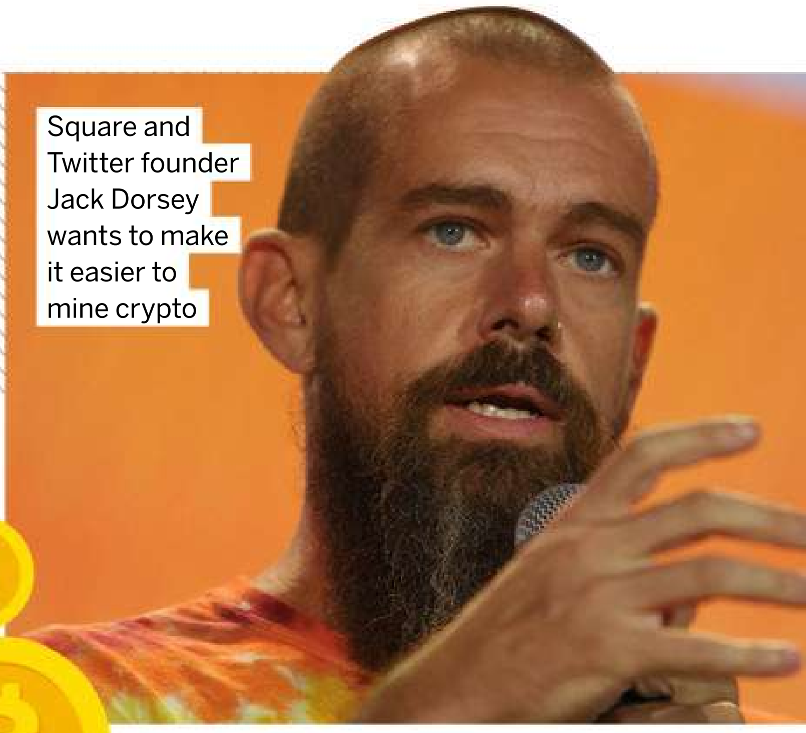
HOW ₿ITCOIN MINING WORKS

Discover the tools that Bitcoin miners use to gain valuable cryptocurrency

WORDS MARK SMITH

DID YOU KNOW? The first-ever Bitcoin transaction took place in 2010, when a man in Florida paid 10,000 BTC for two pizzas

Masses of servers are used for mining cryptocurrencies


Square and Twitter founder Jack Dorsey wants to make it easier to mine crypto

It was in the late-1800s that hundreds of thousands of prospectors descended on the Klondike in Canada to mine for gold. It was known as the 'gold rush', and some of them found their fortunes. Many didn't find anything at all - and over a century later people are trying the same thing. But this time, instead of spades and pickaxes, they're using computers. It's known as 'crypto mining' and since the launch of the first cryptocurrency, Bitcoin, in 2009, more and more people have tried to find their fortune by mining it and other virtual currencies. You may have heard of Bitcoin, but there are many more cryptocurrencies out there – over 5,000, in fact.

Cryptocurrency is virtual money. Unlike ordinary cash, which has its value controlled by governments and banks, crypto is stored on something called a virtual ledger, which is like a database – a computer program for recording information. When crypto passes between two people in the virtual world, say, to buy something, the transaction is stored on something called a 'distributed ledger', also called a blockchain.

Whereas an ordinary database can be changed by one person, lots of people have access to that one distributed ledger. This gives the information stored on it – such as the fact someone has paid for something with Bitcoin – very difficult to fake or make inaccurate.

The transaction can be 'trusted' to have really taken place, giving the virtual money real-world value. These bits of information, which are added to the blockchain, are called 'blocks'.

The fact it works this way also means crypto is not controlled by any one organisation, bank, government or individual, but by the community that uses it. Once that transaction is agreed, it can be used to buy goods and services, just like in the real world.

You can buy crypto using real money on an online currency exchange. Buchi Okoro, CEO and cofounder of African crypto exchange Quidax, says: "Nobody owns it, but anyone who has a link can contribute to it. And as different people update it, your copy also gets updated."

EAST VS WEST

The race to mine crypto has seen the balance of power shift back and forth between nations in recent years. The most recent development saw the US overtake China as the country with the largest amount of Bitcoin mining. The figures demonstrate the impact of a crackdown on Bitcoin trading and mining launched by the Chinese government in late May 2021, which devastated the industry and caused miners to shut up shop or move overseas. Other major mining operations are centred around Russia and Eastern Europe, with mining farms that are truly vast in scale.

There has been a major crackdown on Bitcoin in China

An engineer on a cherry picker adjusts mining rigs at the CryptoUniverse cryptocurrency mining farm in Nadvoitsy, Russia

© Getty

There are a few reasons that people use crypto. One is that it's semi-anonymous, and another is that it's simple to use and can be transferred between a buyer and a seller quickly online. Also, its value doesn't change depending on what's happening in any one country, such as rising interest rates or job losses. In September 2021, El Salvador became the first country in the world to adopt Bitcoin as legal tender.

The creation of Bitcoin is referred to as 'Bitcoin mining', and it involves adding new blocks to the blockchain. The people who do this are all taking part in a worldwide competition known as the 'mining race' – think of it as a 21st-century gold rush. To take part, miners have to use specialist hardware known as mining rigs. This is computer equipment that creates new blocks to be added to the blockchain. It does this by solving complex mathematical problems. If they're successful, they can get two types of rewards.

The first is the block reward, which is issued to the publisher of every block. Think of it as a pat on the back for a job well done. The second reward is a transaction fee – fractions of Bitcoins paid by a private user who is making a transaction. This fee helps incentivise the miner to include these transactions in published blocks. In essence, they're being paid to record the transaction.

Perhaps because it was the first or most famous crypto, Bitcoin mining is dominated by big players now rather than individuals. The biggest Bitcoin mining rig is said to consist of $300,000,000 (£218,000,000) worth of application-specific integrated circuit computers. But miners with smaller operations have turned their hand to other crypto, such as Ethereum and Zilliqa. The price of Bitcoin jumped recently when Square CEO Jack Dorsey – who also founded Twitter – said that he wanted his digital payments company to build software which would make it easier for everyday people to mine crypto. He tweeted: "Mining needs to be more distributed. The more decentralised this is, the more resilient the Bitcoin network becomes."

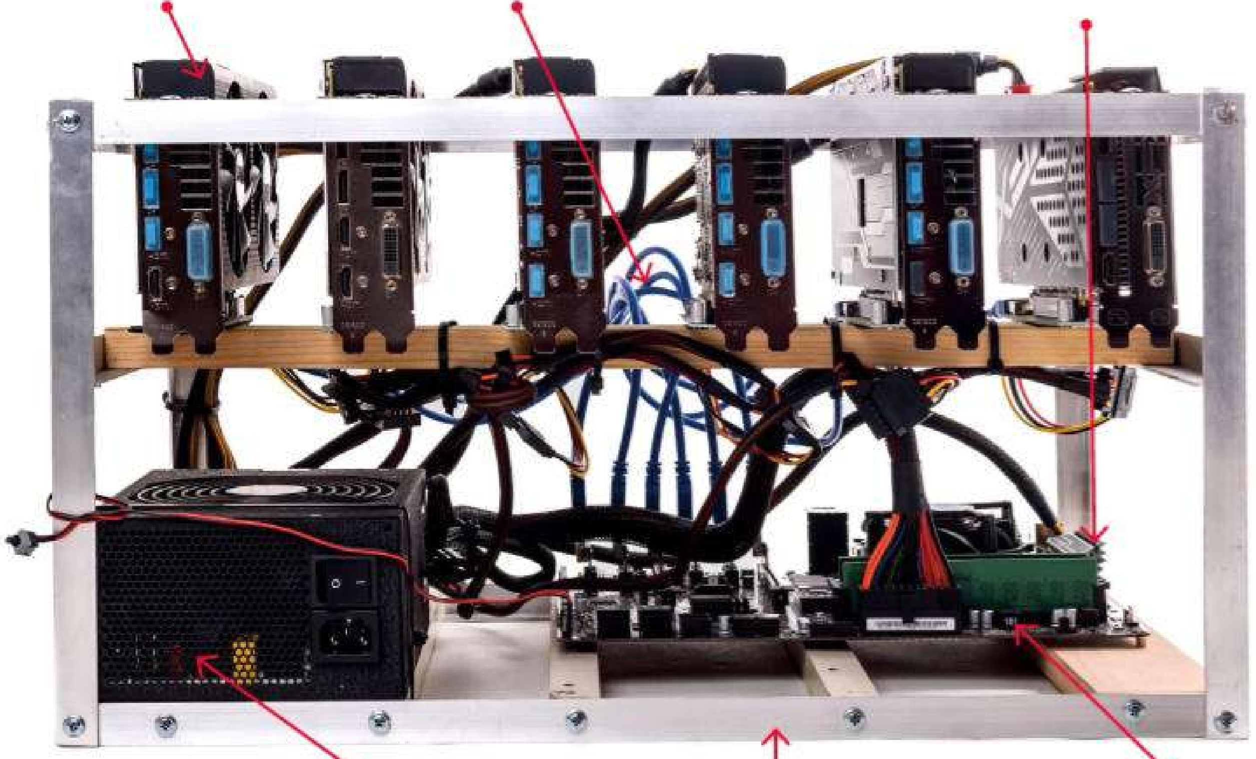
Did you know?

Bitcoin is limited; once it's all mined, that's it

> "Miners have to use specialist hardware known as mining rigs"

MINING RIGS

The devices used to mine crypto can be the size of a desktop computer or truly vast, taking up entire buildings



GRAPHICS CARDS
Linked graphics cards provide the computation power behind the mining process.

RISER CABLES
These connect the six graphics cards to the motherboard and allow spacing between cards to stop too much heat building up.

OPERATING SYSTEM
Each rig has an operating system, which can be Windows or something like NiceHash OS, Hive OS or RaveOS.

POWER SUPPLY
Pretty much the same as you'd find on a desktop PC, this keeps the whole rig operational.

METAL FRAME
This case is what keeps everything in place, and should be open to the air to allow heat to escape.

MOTHERBOARD/CPU
Like a PC, the motherboard and CPU are the brains of the whole rig, allowing it to regulate its components.

Bitcoin mining is having a detrimental impact on the environment, say some experts

MINING'S COST TO PLANET EARTH

Traditional types of mining are known for their potential to negatively impact the planet, and Bitcoin mining is no different. With vast amounts of energy needed to power computerised rigs, it's thought the total amount of power needed to mine Bitcoin worldwide is more than that used by some countries.

In the last year, the total crypto-mining power consumption soared to the equivalent of the annual carbon footprint of Argentina. A single transaction made with Bitcoin has the same carbon footprint as 680,000 Visa transactions or 51,210 hours of watching YouTube. Benjamin Jones, a professor of economics at the University of New Mexico, said the amount of electricity used to mine Bitcoin "has historically been more than [electricity used by] entire countries, like Ireland".

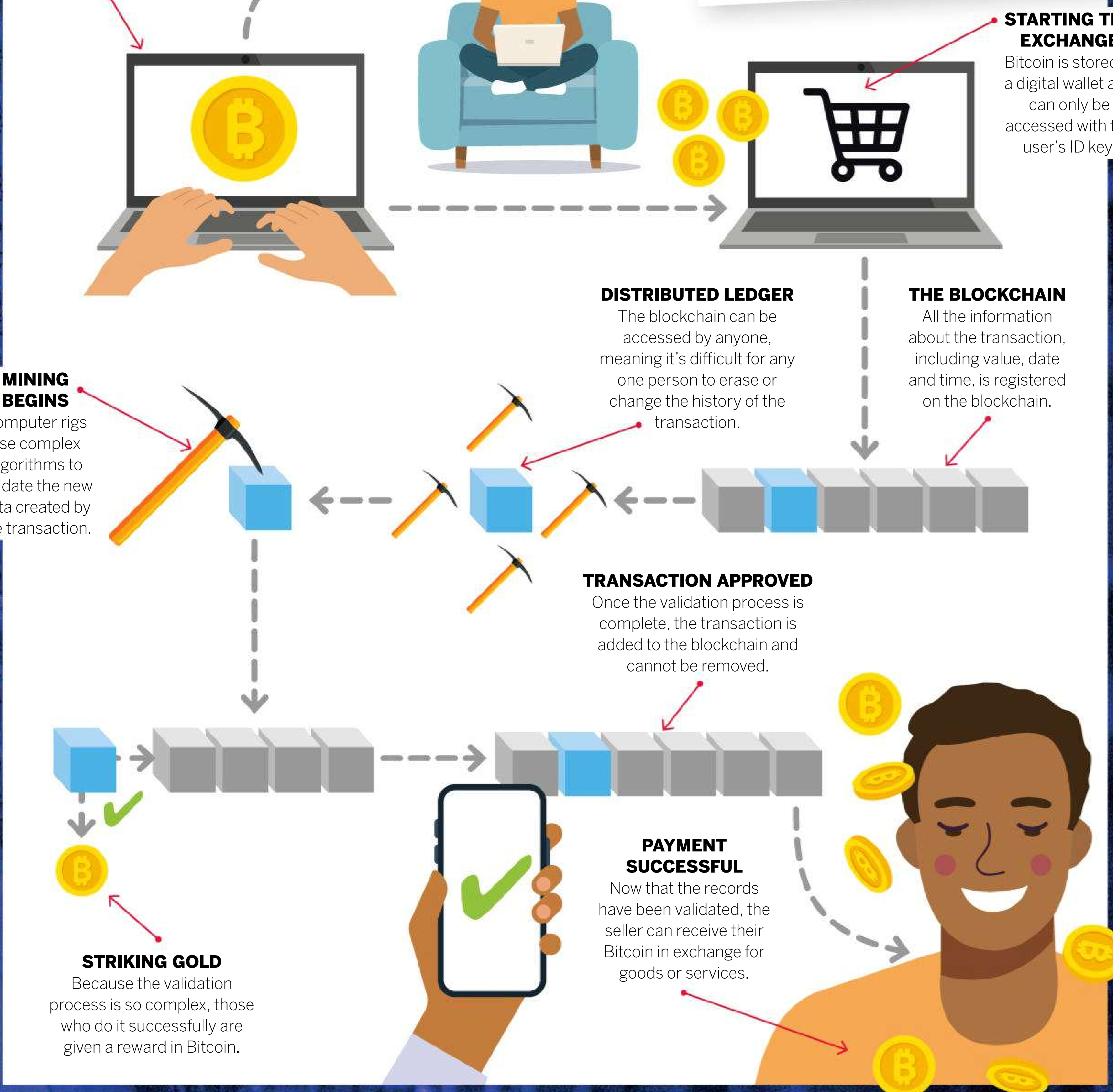
DID YOU KNOW? No one knows who created Bitcoin. People believe it's Satoshi Nakamoto, whose real identity is unknown

MONEY FROM THE ETHER

Creating new crypto can be a rewarding process with the right equipment

CAJA EXCLUSIVA DE
bitcoin

El Salvador became the first country in the world to adopt Bitcoin as legal tender



BUYING POWER
Users can exchange Bitcoin and other crypto for real-world products and services.

STARTING THE EXCHANGE
Bitcoin is stored in a digital wallet and can only be accessed with the user's ID key.

DISTRIBUTED LEDGER
The blockchain can be accessed by anyone, meaning it's difficult for any one person to erase or change the history of the transaction.

THE BLOCKCHAIN
All the information about the transaction, including value, date and time, is registered on the blockchain.

MINING BEGINS
Computer rigs use complex algorithms to validate the new data created by the transaction.

TRANSACTION APPROVED
Once the validation process is complete, the transaction is added to the blockchain and cannot be removed.

PAYMENT SUCCESSFUL
Now that the records have been validated, the seller can receive their Bitcoin in exchange for goods or services.

STRIKING GOLD
Because the validation process is so complex, those who do it successfully are given a reward in Bitcoin.

© Getty

FOLDING ELECTRIC BIKE TEARDOWN

How It Works takes apart the Xiaomi MiJia QiCycle

WORDS **AILSA HARVEY**

Combining clever mechanical and electrical engineering, this folding electric bike aims to make travelling a more practical process. Boarding a train with a bike can mean navigating tight aisles with a bulky metal frame, while packing it into a car can be a challenge. The QiCycle gets around this by transforming into a much more compact unit. The seat can be pushed right down, the handlebars turned upside down and the frame can be folded in half lengthways.

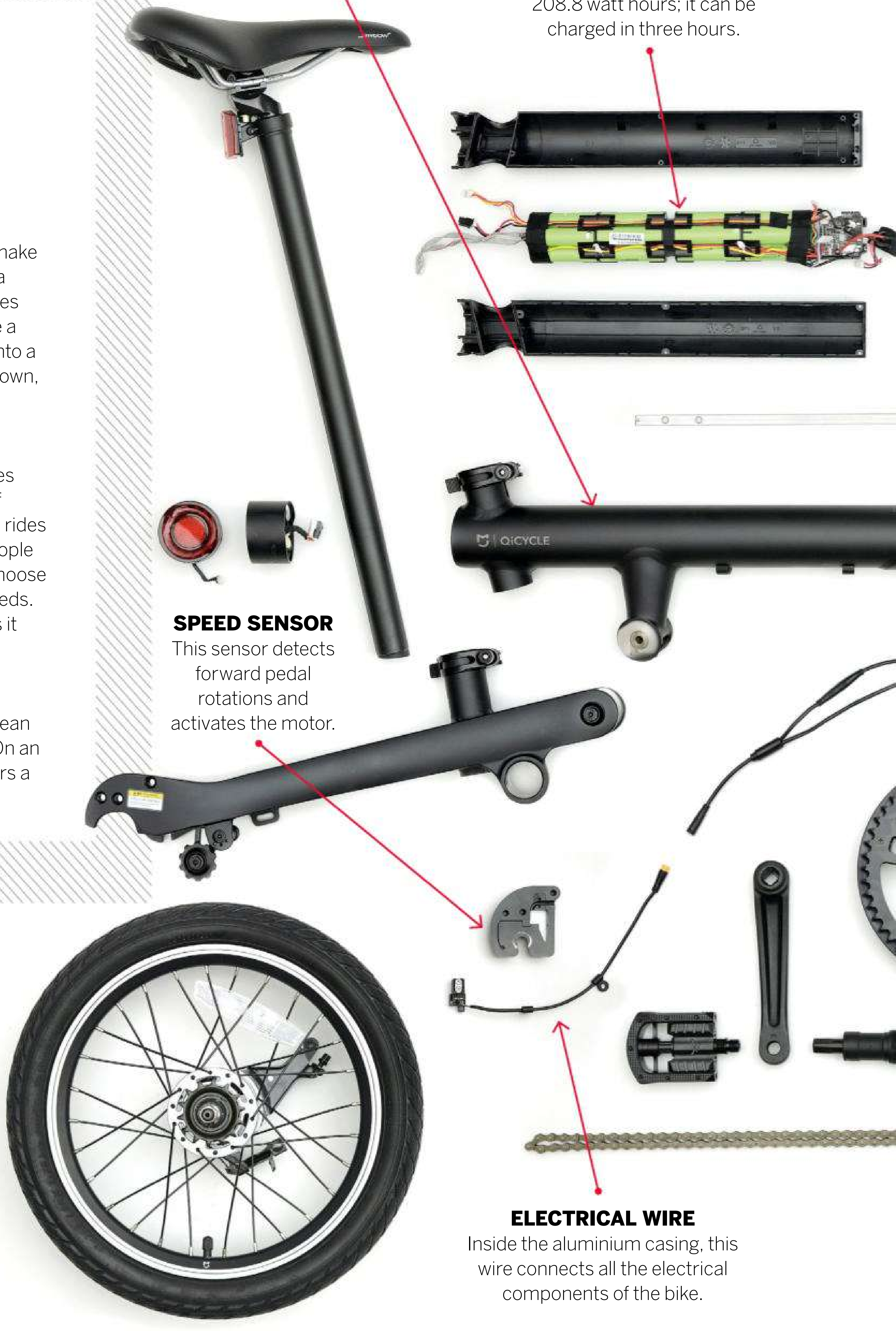
Folding bikes have been around for over a century, but electric versions have only emerged in the last two decades after improvements in battery design. The combination of human pedal power and electric power makes longer bike rides achievable for people of nearly any age or fitness level. People can travel farther and faster with electric bikes, and can choose when to turn on electrical pedal assistance to suit their needs. With both electric and folding qualities, the QiCycle makes it easier to travel with and on the bike.

The QiCycle has small wheels – a common feature with folding bike models as it limits the width of the bike when folded. In non-electric bikes, a smaller wheel size would mean the rider would have to work harder over long distances. On an electric folding bike, though, each push of the pedal triggers a motor that propels the rider forward with ease.

The QiCycle has small 40-centimetre wheels

COMPACT COMPONENTS

Explore the engineering of this space-saving bike



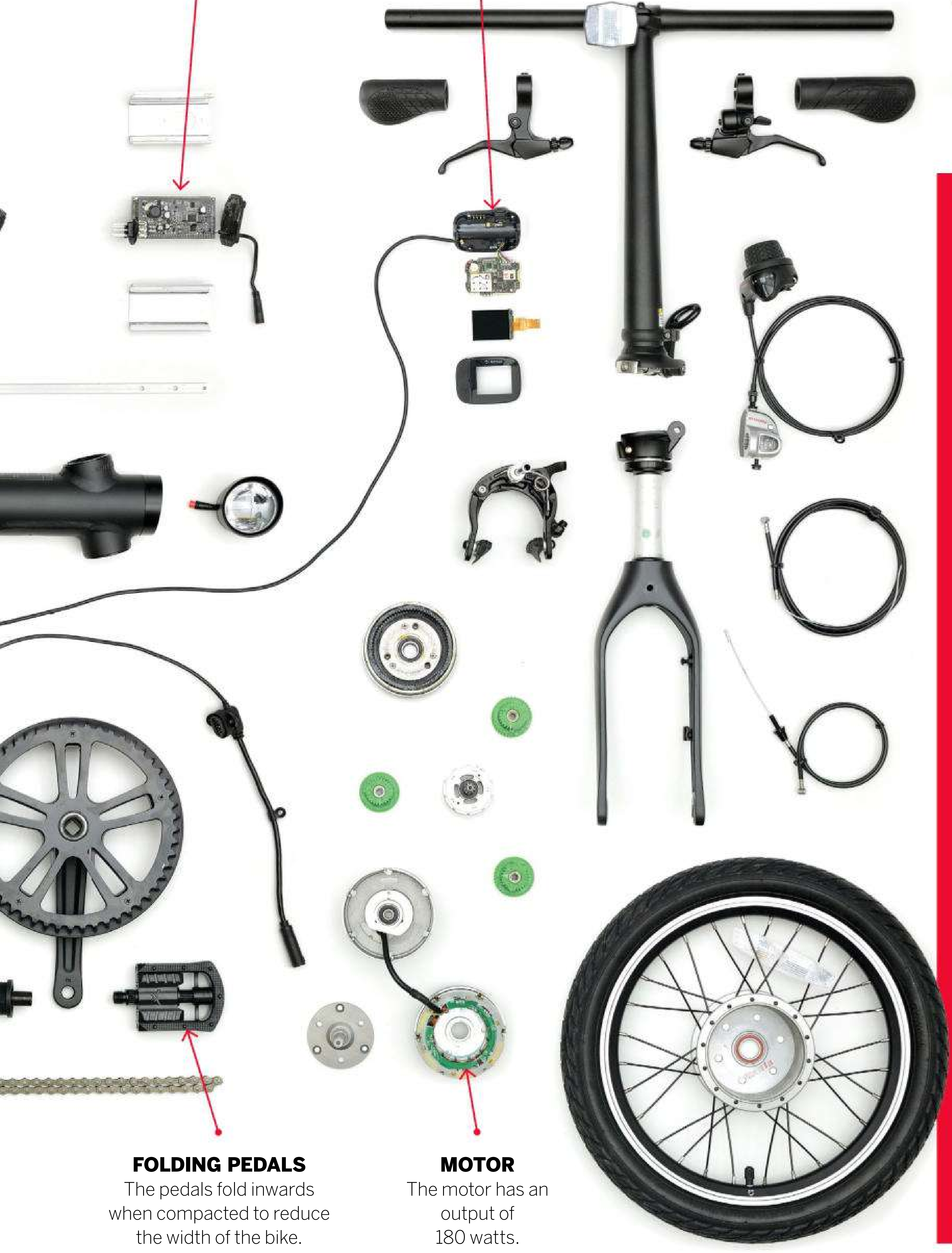
ALUMINIUM FRAME
The aluminium skeleton weighs 5.5 kilograms. This makes up about a third of the bike's weight.

BATTERY
The bike's battery capacity is 208.8 watt hours; it can be charged in three hours.

SPEED SENSOR
This sensor detects forward pedal rotations and activates the motor.

ELECTRICAL WIRE
Inside the aluminium casing, this wire connects all the electrical components of the bike.

DID YOU KNOW? Englishman William Grout is credited with the invention of the first folding bike in 1878



CONTROL UNIT
The brain of the bike takes energy from the battery and directs it to the motor. It also connects to the pedals, display and other sensors.

NEXUS THREE-SPEED HUB
Gear shifting changes the level of electric assistance used when pedaling. More electricity increases the power produced by the motor per pedal.

FOLDING PEDALS
The pedals fold inwards when compacted to reduce the width of the bike.

MOTOR
The motor has an output of 180 watts.

Did you know?
Electric bike sales are expected to reach 40 million by 2023

When folded, the wheels come together and the handlebars fold downwards

BUILT-IN COMPUTER

To set up the Xiaomi MiJia QiCycle's computer, you first need to download the QiCycle smartphone app and scan the barcode shown on the computer with your phone camera. This synchronises details such as the time to match those on your phone.

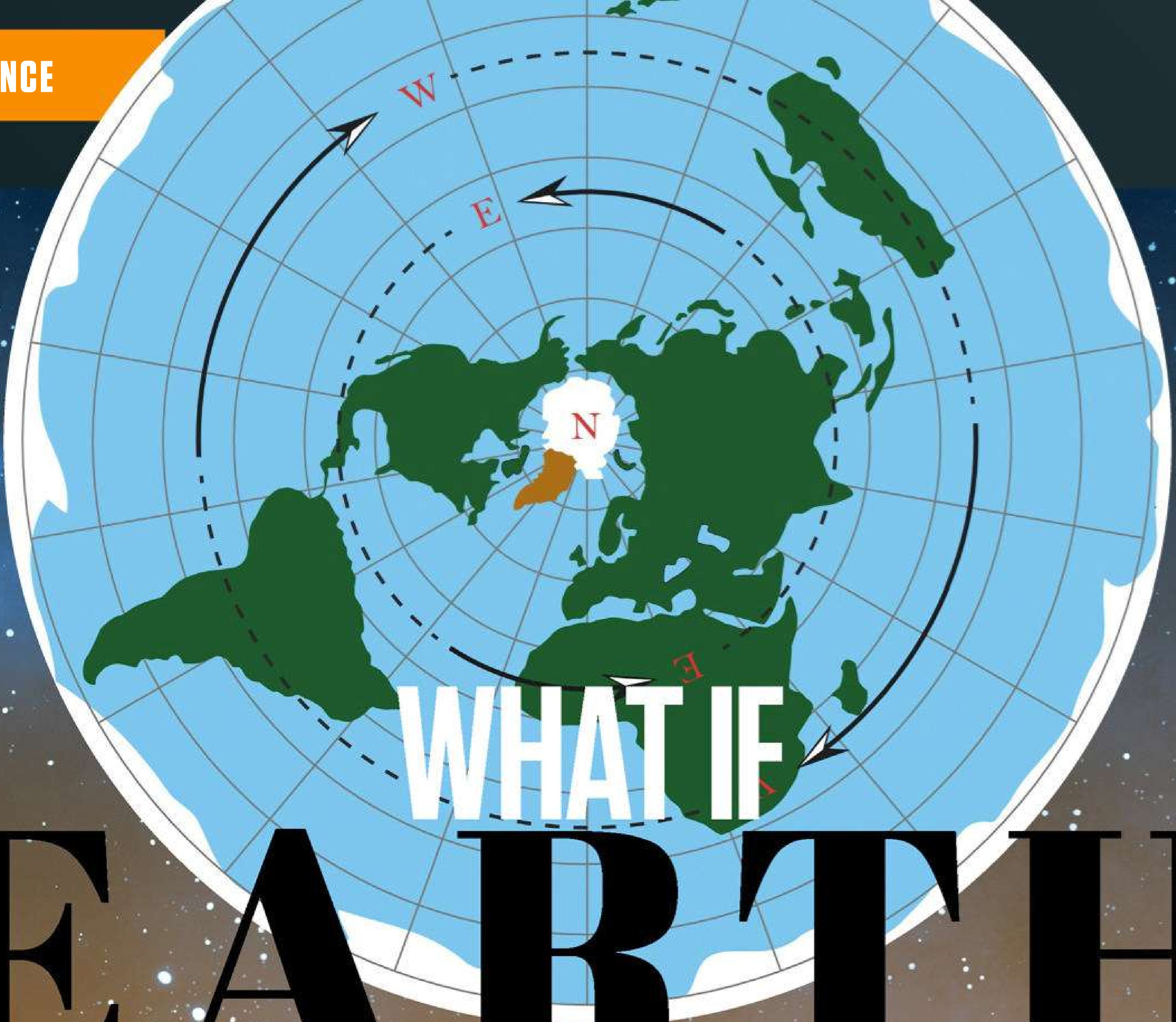
As the rider starts to pedal, the speed of the bike will automatically display on the computer screen in real time. Using the arrows on the computer, the level of electrical assistance can be altered. The bike has four modes: enhanced, balanced, eco and off. Enhanced mode has the highest power assistance, while the 'off' mode uses no electricity. Holding down the up arrow turns on the bike's lights when cycling at night.

The accompanying smartphone app displays extra information such as calories burned while riding, the bike's battery level as a percentage and the distance travelled on the bike. While the built-in computer is best for monitoring live performance while riding, the app stores the bike's historical data.

QICYCLE
13:42
SPEED
5.1
加强
平衡
经济
健身
WATT
0
DIST
0.0

Battery level, speed, distance and power can be viewed on the bike computer

© iFixit



WHAT IF EARTH WAS FLAT?

Eight ways our world would get weird if we really lived on a disc

WORDS **DAISY DOBRIJEVIC**

Earth – the Blue Marble – is our very much spherical home. Humankind has been aware of this for more than 2,000 years, ever since the ancient Greek academic Pythagoras proposed its spherical shape back in 500 BCE. Eratosthenes then calculated its circumference around 240 BCE. But let's imagine that Earth is flat. After all, there are many out there who truly believe that this is the case. How would everyday life function? Would it function at all? Here we explore how much of an oddball – or 'oddslice' – Earth would be if it were flat and whether there are any advantages to living on a strange disc with the Sun and Moon rotating overhead like characters on a cosmic carousel.

DID YOU KNOW? At the equator, the circumference of Earth is around 25,000 miles

Aurora photographed by NASA astronaut Jack Fischer aboard the International Space Station

1

NO MORE AURORAE, AND WE'D ALL BE ROASTED

On spherical Earth, the swirling molten metal surrounding our iron core generates electric currents, which in turn create our protective magnetic field, curving around the planet from one pole to the other. But on a flat Earth, without a solid core generating a magnetic field, we would lose our protective layer, called the magnetosphere. Charged particles from the Sun would no longer interact with our magnetosphere to create incredible auroral light shows. Though the absence of aurorae would be the least of our worries, as Earth would no longer be protected from the solar wind. We'd be bombarded with harmful solar radiation that could strip Earth of its protective atmosphere, leaving a barren world akin to our neighbour, Mars.

2

EVERYONE WOULD SHARE THE SAME VIEWS OF THE NIGHT SKY

On a flat Earth there would be no Northern or Southern Hemisphere, and our night sky would look the same wherever you were in the world. It sure would make stargazing easier, as you wouldn't have to travel to a different hemisphere to tick off all the targets on your astronomy bucket list. But isn't that all part of the fun? If we all shared one view of just one portion of the night sky, we'd miss out on the many discoveries that have been made through our enjoyment of a 360-degree view of the observable universe.

On a flat Earth, we would all have the same view of the sky

Hurricane Florence photographed from the ISS

3

HURRICANES WOULD BE A THING OF THE PAST

Every year, hurricanes, formed over the North Atlantic and Northeast Pacific; typhoons, formed over the Northwest Pacific, and cyclones, formed over the South Pacific and Indian Oceans, cause unprecedented damage. In 2017 Hurricane Harvey alone caused $125 billion (£90 billion) worth of damage in the US.

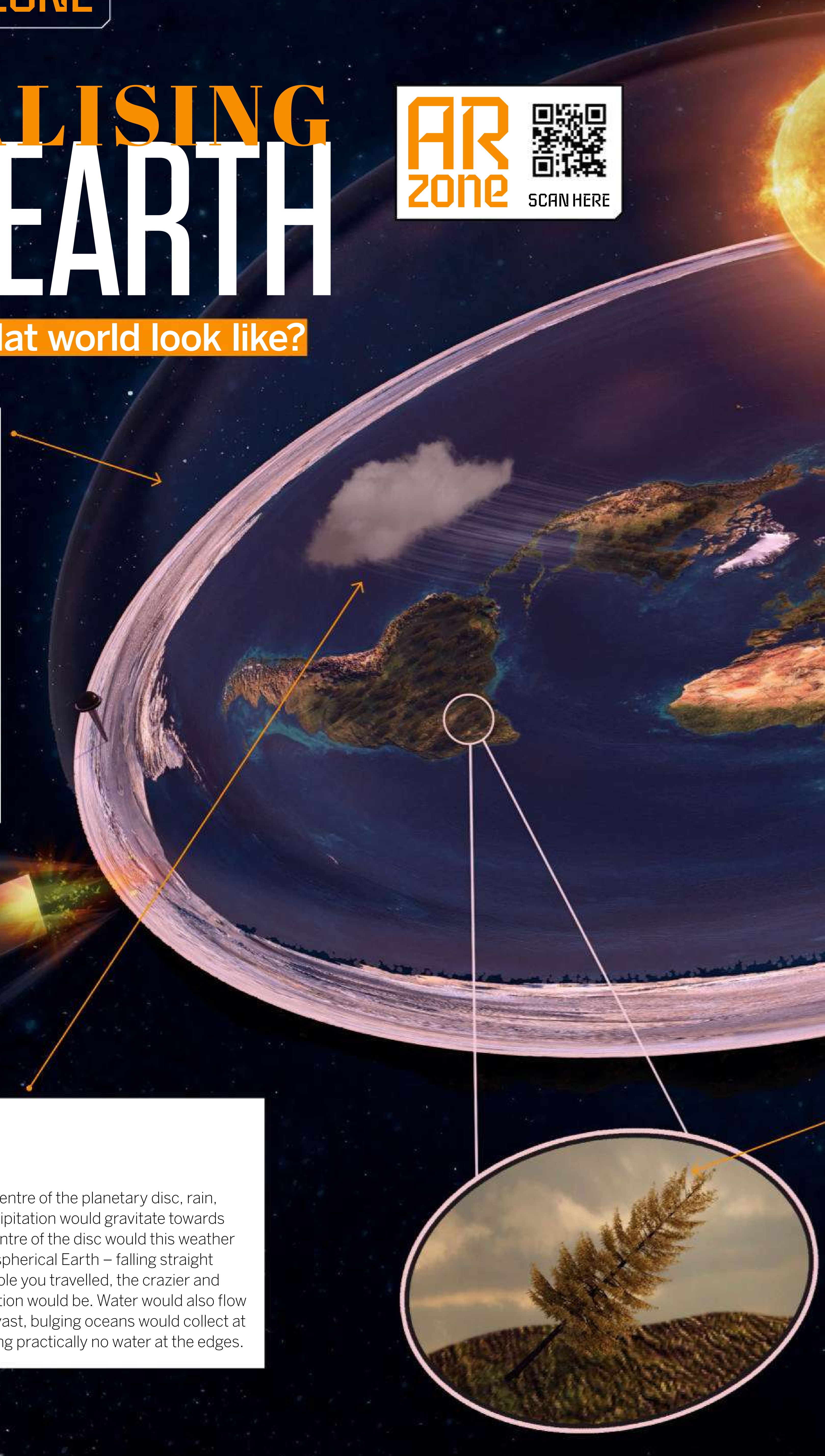
The devastating rotating nature of these tropical storms stems from Earth's Coriolis force, which causes those in the Northern Hemisphere to rotate clockwise and those in the Southern Hemisphere to rotate counterclockwise. However, on a stationary, flat Earth, no Coriolis force would be generated. No Coriolis means no hurricanes, typhoons or cyclones. This is also why we don't see these storms between five degrees north and south of the equator, as the Coriolis magnitude is zero at the equator.

© Getty / Alamy / NASA

VISUALISING FLAT EARTH

What would a flat world look like?

AR zone SCAN HERE



WE'D HAVE NO ATMOSPHERE 5

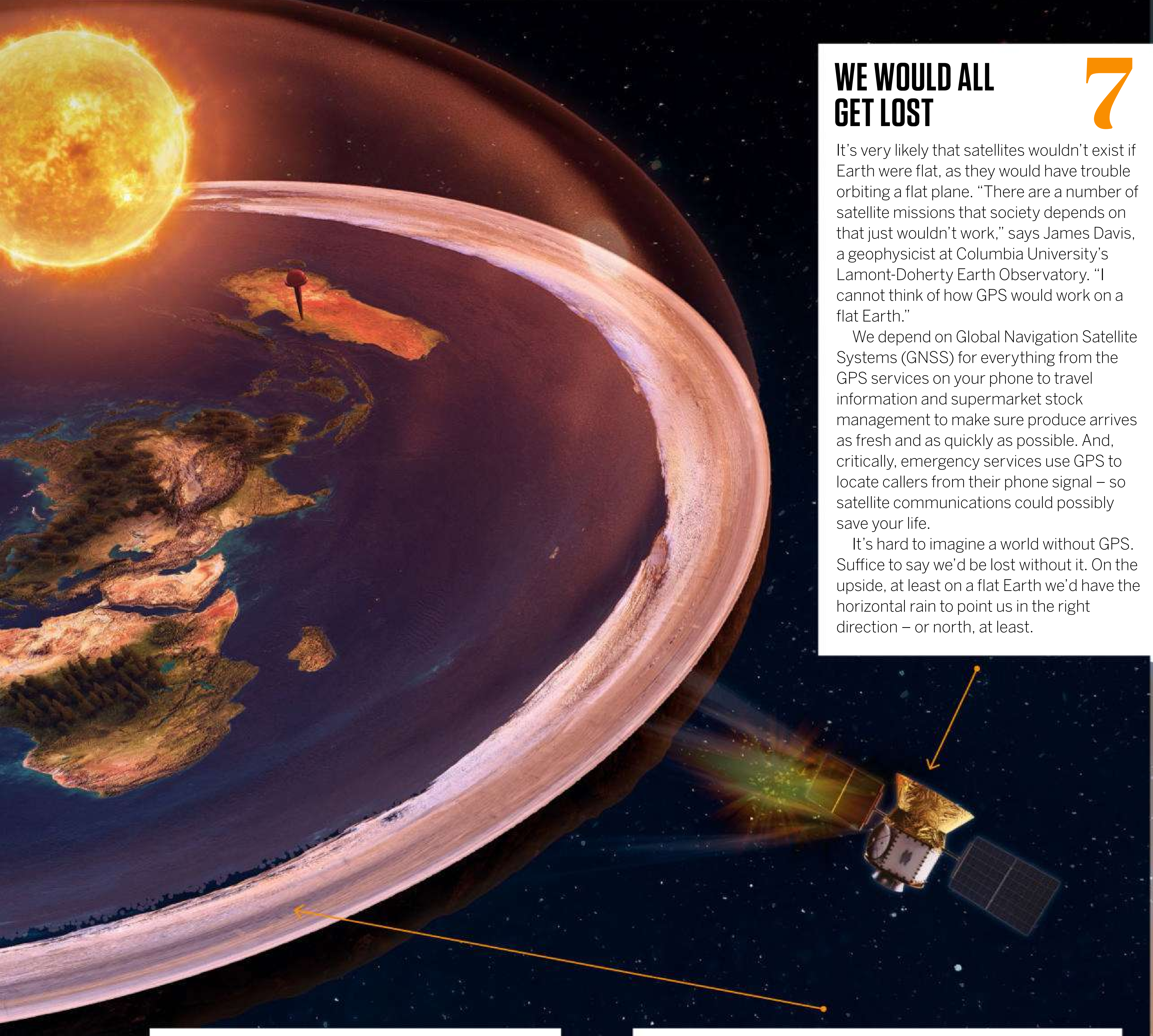
With no gravity, flat Earth would no longer be able to hold onto an atmosphere. Without our planet's protective blanket our skies would turn black, and surface life would cease to exist.

Water would boil away in the vacuum of space, and surface temperatures would plummet. But it isn't all bad news. Deep ocean-dwelling organisms that don't require oxygen (anaerobic bacteria) and those that don't need sunlight to generate food and energy (chemosynthetic bacteria) might just survive. After all, such bacteria have endured long trips in space and lived to tell the tale.

SIDEWAYS RAIN 6

If gravity pulled towards the centre of the planetary disc, rain, snow and other forms of precipitation would gravitate towards the North Pole. Only at the centre of the disc would this weather behave as we know it on our spherical Earth – falling straight down. The further from the pole you travelled, the crazier and more horizontal the precipitation would be. Water would also flow towards the North Pole, and vast, bulging oceans would collect at the centre of the planet, leaving practically no water at the edges.

DID YOU KNOW? For someone 183 centimetres tall, the horizon is just over three miles away



WE WOULD ALL GET LOST

7

It's very likely that satellites wouldn't exist if Earth were flat, as they would have trouble orbiting a flat plane. "There are a number of satellite missions that society depends on that just wouldn't work," says James Davis, a geophysicist at Columbia University's Lamont-Doherty Earth Observatory. "I cannot think of how GPS would work on a flat Earth."

We depend on Global Navigation Satellite Systems (GNSS) for everything from the GPS services on your phone to travel information and supermarket stock management to make sure produce arrives as fresh and as quickly as possible. And, critically, emergency services use GPS to locate callers from their phone signal – so satellite communications could possibly save your life.

It's hard to imagine a world without GPS. Suffice to say we'd be lost without it. On the upside, at least on a flat Earth we'd have the horizontal rain to point us in the right direction – or north, at least.

SAY GOODBYE TO GRAVITY… AT LEAST AS WE KNOW IT

4

On spherical Earth gravity pulls equally from all sides no matter where in the world you are. For Earth to take the shape of a disc in the first place, gravity must be having no effect. If it did, it would soon pull the planet back into a spheroid. Maybe a flat Earth would have no gravity at all. Or perhaps a flat Earth would cause gravity to pull to the centre of the disc: the North Pole. The further away from the North Pole, the more horizontal the gravitational tug. This would wreak havoc worldwide, but at least the world long jump record would be easily beaten – as long as you orientated yourself northwards before taking off.

SOME JOURNEYS WOULD TAKE FOREVER

8

Longer travel times would be expected, not just from getting lost due to a lack of GPS, but also the distances we would need to travel. According to flat Earth belief, the Arctic lies in the centre of the planet, and Antarctica forms a giant 'ice wall' around the edge, which conveniently stops people falling off. But if you're unable to fly around the globe, and instead are forced to fly 'across' it, then travel times significantly increase. For example, to fly from Australia, which is on one side of the flat Earth map, to a part of Antarctica that lies on the other side, you'd need to fly across the whole Arctic, as well as North and South America. You can also forget about trips across Antarctica – which has been achieved – as it'd be impossible due to that pesky ice wall.

© Getty / Alamy / Illustration by Nicholas Forder

WHAT ARE ANTIOXIDANTS?

The protective chemicals found in fruit, vegetables and other foods are lifelines to our health

WORDS **JENN HALWEIL & SKYLAR WALTERS**

Antioxidants are substances – artificial or natural – that prevent and slow cell and tissue damage by attacking free radicals, which are molecules that have an unpaired electron. Free radicals are natural by-products of our metabolism and are also generated in response to environmental stressors, such as exposure to pollution, X-rays or cigarette smoke.

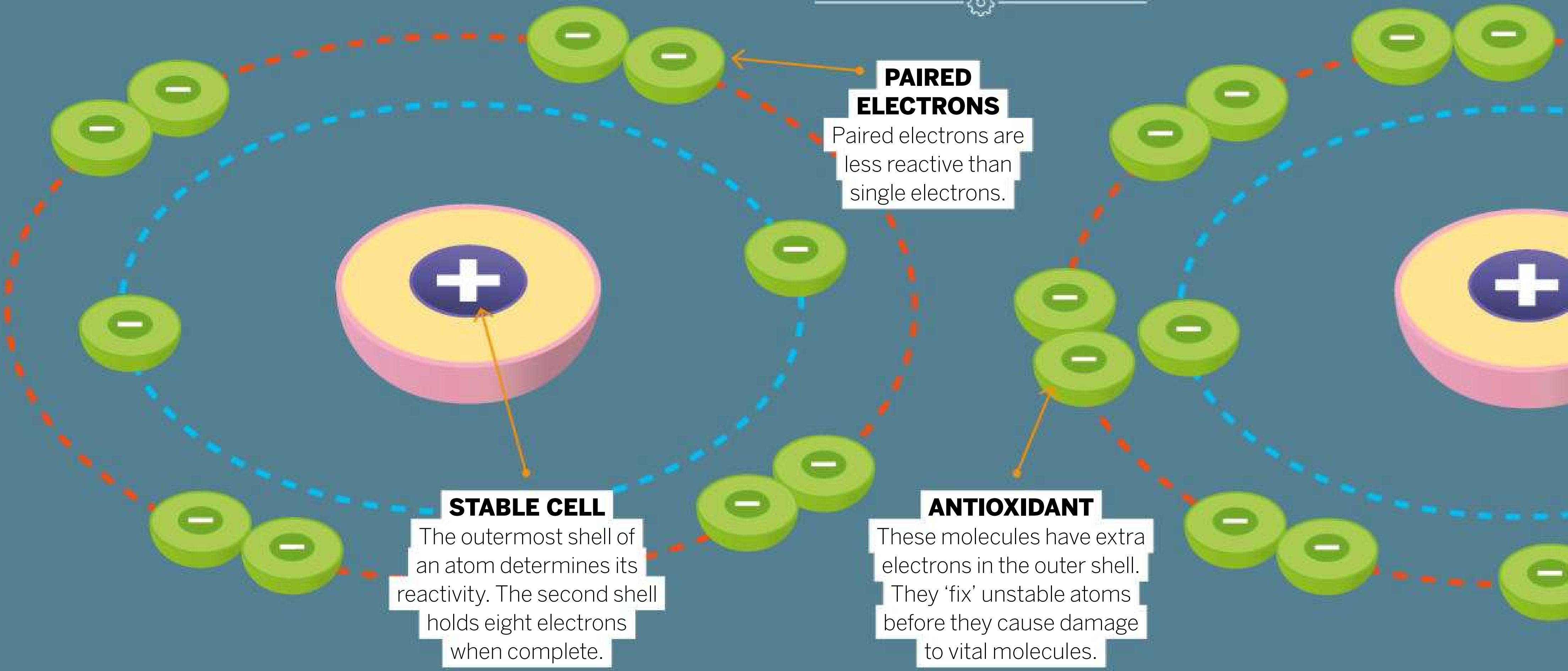
In high quantities, free radicals can cause oxidative stress, which is when the body has too many free radicals that start to destroy DNA, fatty tissue and proteins. This is where antioxidants can save the day. Unlike free radicals, antioxidants have extra electrons. This means that they can pass their surplus electrons to free radicals, stabilising the free radicals so they can no longer damage the body's cells and tissues. In doing so, antioxidants ward off or slow oxidative stress, preventing serious illnesses.

Oxidative stress has been associated with illnesses such as cancer, heart disease and some neurodegenerative diseases, including Alzheimer's and Parkinson's disease. The best way to increase antioxidants in the body and maintain a healthy balance of free radicals is to incorporate antioxidant-rich foods into your diet.

Generally, the darker the chocolate, the higher the antioxidant level

HOW DO THESE MOLECULES STABILISE OTHERS?

Our bodies depend on donations from antioxidants



PAIRED ELECTRONS
Paired electrons are less reactive than single electrons.

STABLE CELL
The outermost shell of an atom determines its reactivity. The second shell holds eight electrons when complete.

ANTIOXIDANT
These molecules have extra electrons in the outer shell. They 'fix' unstable atoms before they cause damage to vital molecules.

DID YOU KNOW? Blueberries have the highest antioxidant level of all commonly consumed fruit and vegetables

COMMON ANTIOXIDANTS

The term ‘antioxidant’ is often used to describe different foods, but it more accurately describes a chemical property. Any substance that can strip free radicals of their damaging properties is considered an antioxidant. Researchers have discovered hundreds of substances that fit the antioxidant description, and there are bound to be thousands more.

Vitamin C and vitamin E are two of the most common antioxidants found in food. In addition to fighting free radicals, vitamin C supports the immune system and helps repair bones, teeth and cartilage. Vitamin E is a powerful tool in maintaining eye health, producing hormones that regulate blood pressure and repairing muscles after exercise.

Carotenoids – a class of compounds found in fruits and vegetables that are red, orange and yellow – are also well-known antioxidants. Antioxidant carotenoids include beta-carotene, lycopene, lutein and zeaxanthin. However, taking high doses of some carotenoid supplements, such as beta-carotene, can increase health risks, such as an increased chance of lung cancer in smokers. Other antioxidants include selenium, allicin, glutathione, flavonoids and curcumin – all found naturally in foods such as turmeric, apples and even wine.

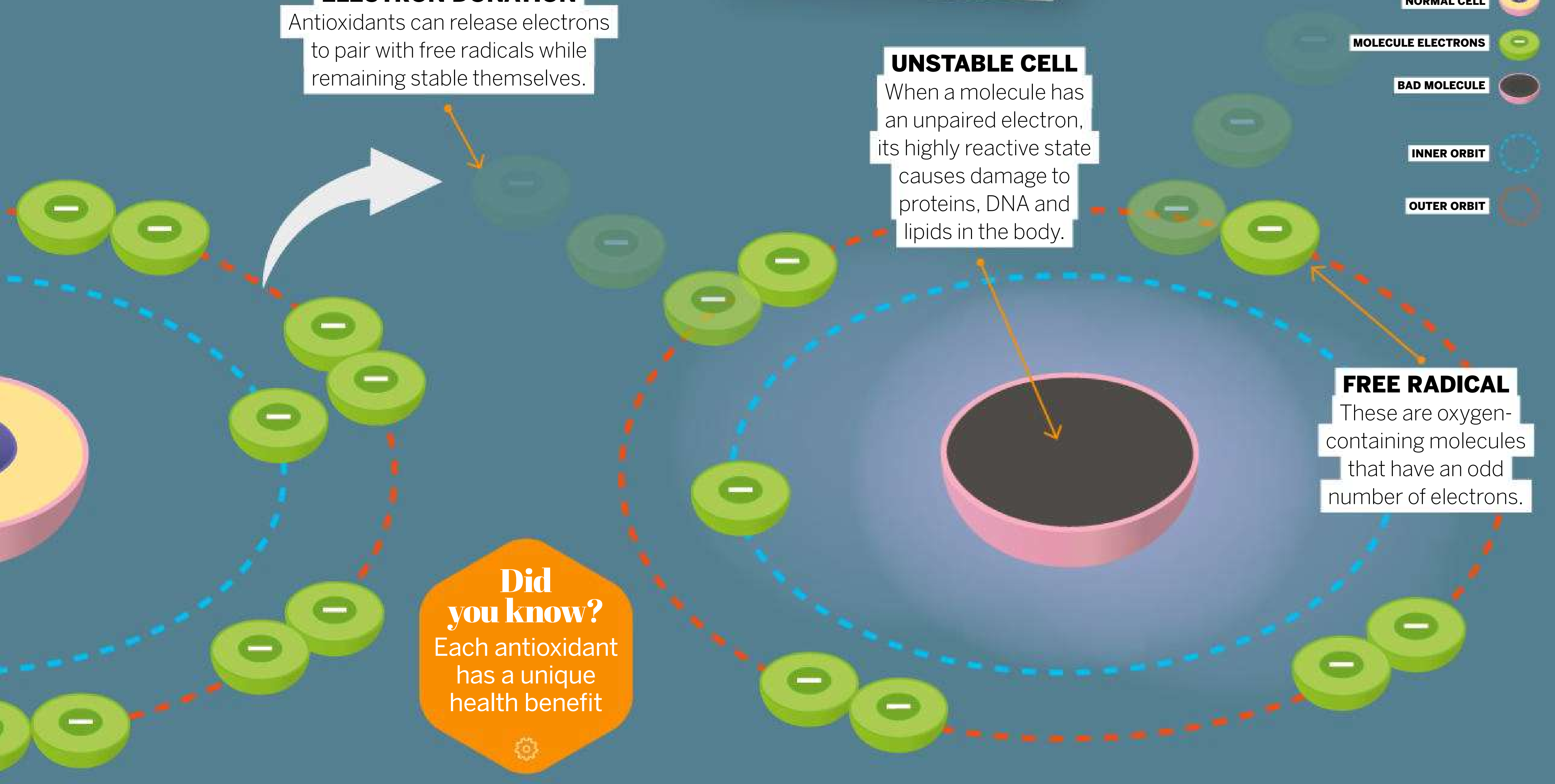
Antioxidant supplements are available, but natural sources are safer as an excess can become damaging

The antioxidant anthocyanin is present in many red, purple and blue plants

Nuts and whole grains provide valuable antioxidants

WHERE CAN THEY BE FOUND?

Antioxidants are most often in fruits, vegetables and legumes, although they can be found in almost every food group. Fruits contain essential nutrients such as potassium, fibre and folate – nutrients that help maintain blood pressure, lower cholesterol and repair body tissues. Blueberries, cranberries, apples, strawberries and more are all filled with antioxidants. Dried fruits – although often high in processed sugars – have a higher antioxidant ratio than fresh fruits, since they lose mass from water. They act as quick antioxidant fuel due to their high concentration of antioxidants. Carotenoids are found in red, orange or yellow vegetables. Many green vegetables such as kale, broccoli and spinach are excellent sources of antioxidants, namely quercetin and lutein.



ELECTRON DONATION
Antioxidants can release electrons to pair with free radicals while remaining stable themselves.

UNSTABLE CELL
When a molecule has an unpaired electron, its highly reactive state causes damage to proteins, DNA and lipids in the body.

FREE RADICAL
These are oxygen-containing molecules that have an odd number of electrons.

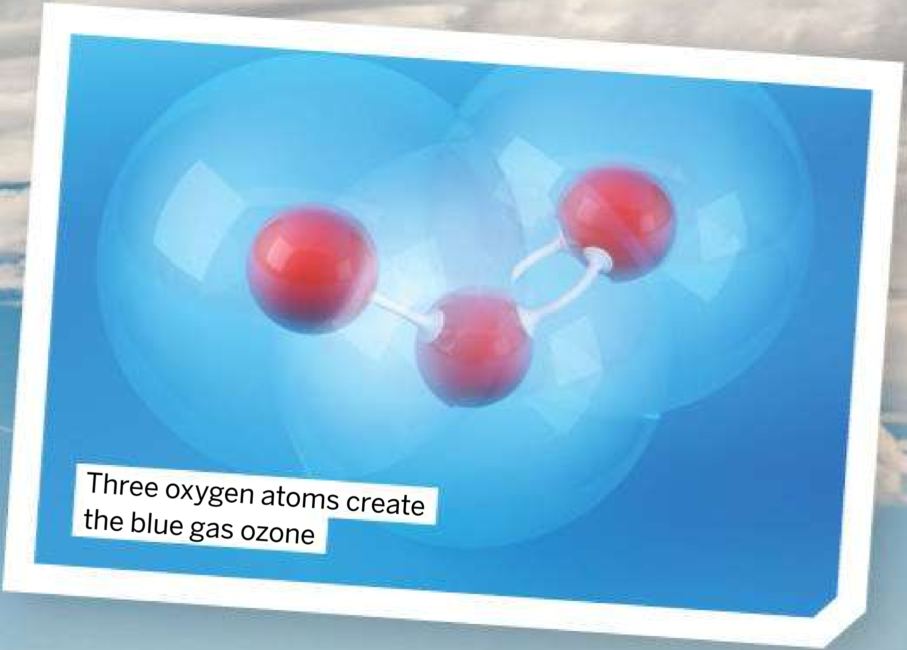
Did you know?
Each antioxidant has a unique health benefit

© Getty / Alamy

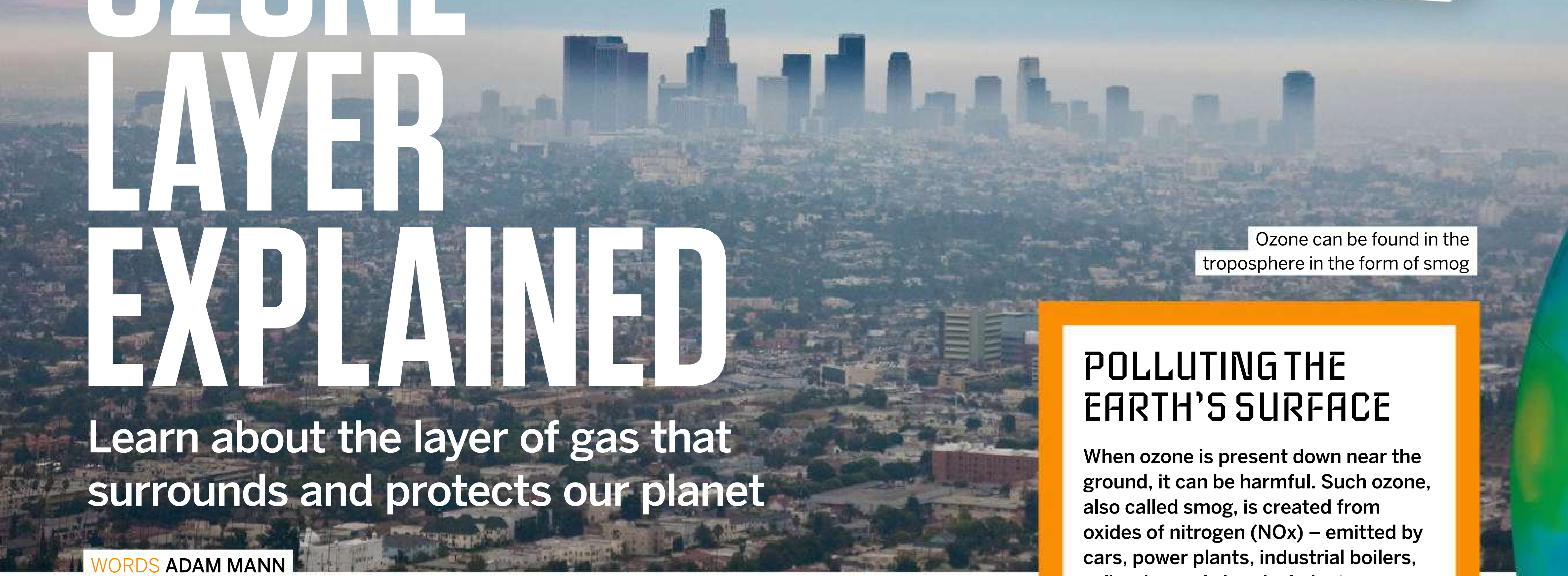
THE OZONE LAYER EXPLAINED

Learn about the layer of gas that surrounds and protects our planet

WORDS ADAM MANN



Three oxygen atoms create the blue gas ozone



Ozone can be found in the troposphere in the form of smog

Ozone is a pale-blue gas composed of three bonded oxygen atoms. It occurs naturally high up in Earth's atmosphere, where it protects the surface from harmful ultraviolet rays – unless dissipated by natural or human phenomena. It's also considered a pollutant, with adverse effects for humans and other creatures when present closer to the ground. Ozone is a relatively unstable substance and can be destroyed by molecules containing nitrogen, hydrogen, chlorine or bromine, which rip ozone's third oxygen atom away from its two partners. Starting in the 1950s, scientists began measuring ozone concentrations above Antarctica, giving them the first hints that there was a problem with the ozone layer.

By the 1980s, researchers were able to map a yearly hole that opened in the ozone layer over Antarctica in the spring, though nobody knew its cause. In 1987, aircraft observations provided unassailable evidence that the ozone hole was being created by human-made pollutants called chlorofluorocarbons (CFCs).

Chlorine and bromine, which are present in chlorofluorocarbons and related compounds, are highly destructive to ozone. A single chlorine atom can rupture more than 100,000 ozone molecules before it leaves the stratosphere. CFCs come from industrial processes like refrigeration and are used in fire suppression and foam insulation, among other applications.

Scientists were able to find that ozone depletion wasn't just occurring over the South Pole, but also in areas over North America, Europe and Asia and much of Africa, Australia and South America. In 1987, countries around the world signed the Montreal Protocol on Substances that Deplete the Ozone Layer, an international document committing signatories to addressing the ozone hole. People have been trying to phase out CFCs and other harmful industrial pollutants ever since.

Did you know?

The ozone layer is 10 to 25 miles above Earth's surface

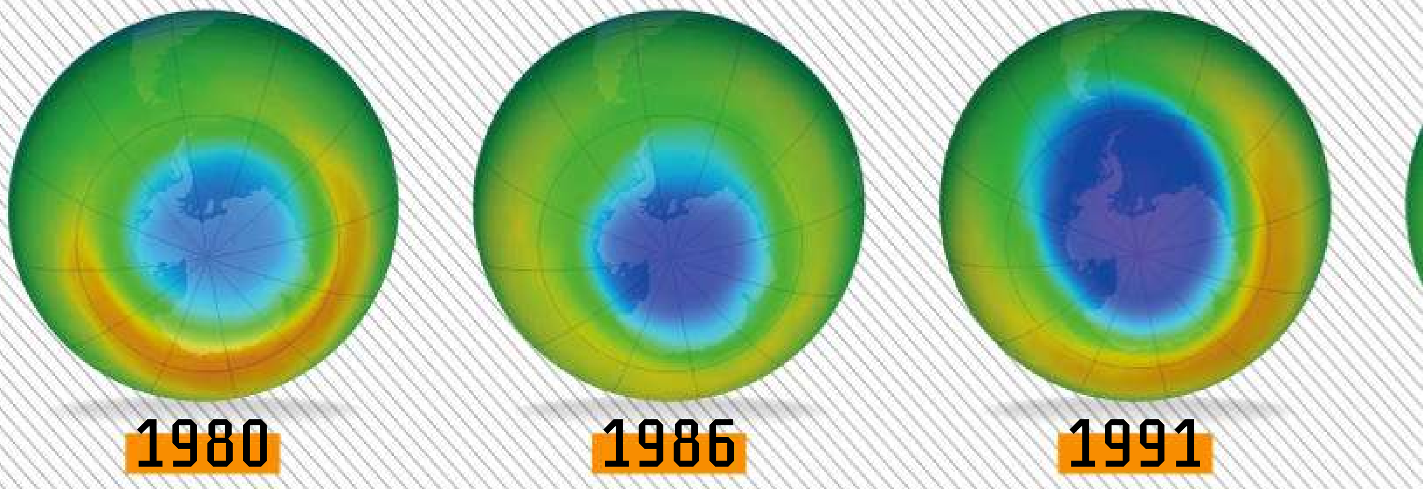
POLLUTING THE EARTH'S SURFACE

When ozone is present down near the ground, it can be harmful. Such ozone, also called smog, is created from oxides of nitrogen (NOx) – emitted by cars, power plants, industrial boilers, refineries and chemical plants – combining with other organic molecules in the atmosphere.

Breathing in ozone can cause chest pain, throat irritation, coughing and damage to lung tissue. It's most dangerous to children and the elderly and those with pulmonary issues like asthma, emphysema and bronchitis. It is also harmful to vegetation and affects forests, parks and wilderness areas. Ground-level ozone can be reduced by limiting pollutants from cars and factories.

A GROWING PROBLEM

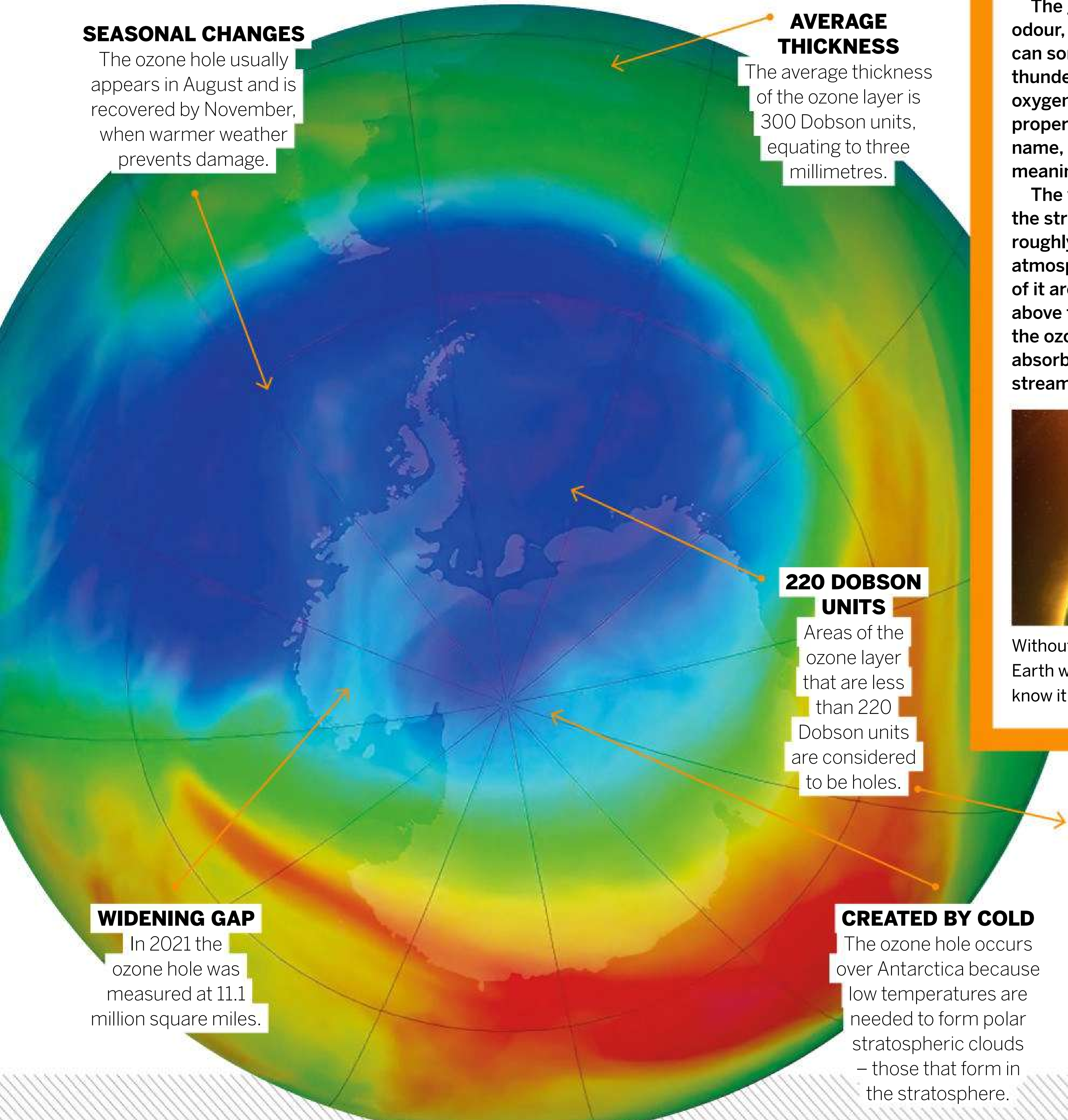
How the ozone hole has shifted over time



DID YOU KNOW? In 2021, the hole in the ozone layer was roughly the size of North America

THE HOLE OVER ANTARCTICA

The ozone layer is much thinner at the poles



SEASONAL CHANGES
The ozone hole usually appears in August and is recovered by November, when warmer weather prevents damage.

AVERAGE THICKNESS
The average thickness of the ozone layer is 300 Dobson units, equating to three millimetres.

220 DOBSON UNITS
Areas of the ozone layer that are less than 220 Dobson units are considered to be holes.

WIDENING GAP
In 2021 the ozone hole was measured at 11.1 million square miles.

CREATED BY COLD
The ozone hole occurs over Antarctica because low temperatures are needed to form polar stratospheric clouds – those that form in the stratosphere.

OXYGEN VS OZONE

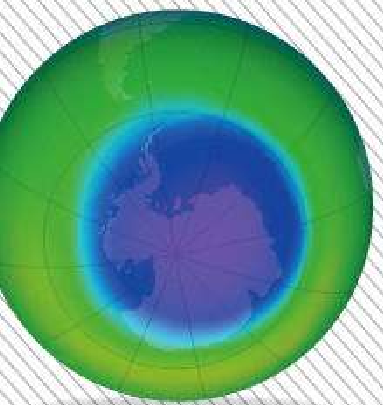
Molecular oxygen (O_2) is the normal oxygen that we breathe, present throughout the atmosphere. It can be split apart by the Sun's rays into two single oxygen atoms, and one of these can then recombine with an O_2 molecule to form O_3 – ozone.

The gas has a distinctive and sharp odour, reminiscent of chlorine, and can sometimes be smelled after a thunderstorm, when lightning zaps oxygen molecules apart. This property is what gives ozone its name, after the Greek word ozein, meaning 'to smell'.

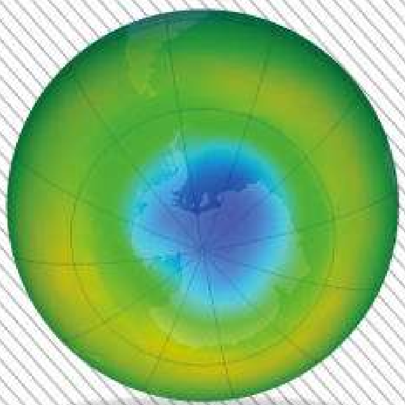
The vast majority of ozone sits in the stratosphere. Ozone makes up roughly 0.00006 per cent of the atmosphere, and peak concentrations of it are present around 20 miles above the surface in an area known as the ozone layer. At that height, ozone absorbs intense ultraviolet radiation streaming in from the Sun.

Without the ozone layer, the ground on Earth would be sterilised and life as we know it wouldn't be possible

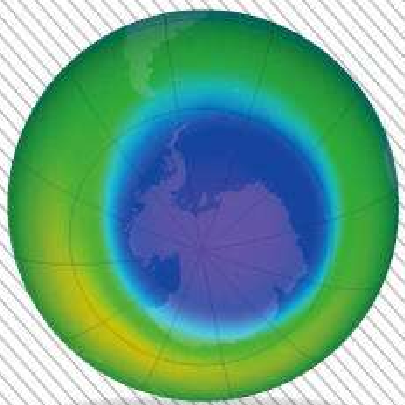
AR zone
SCAN HERE



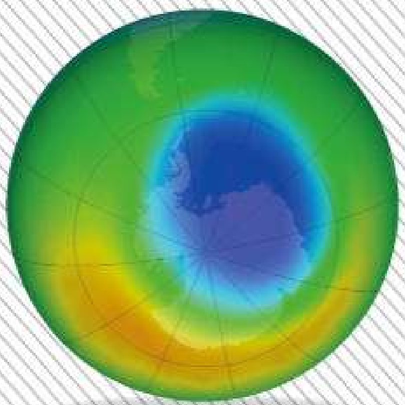
1997



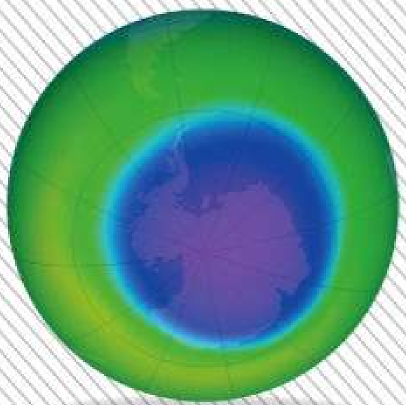
2002



2008



2012



2020

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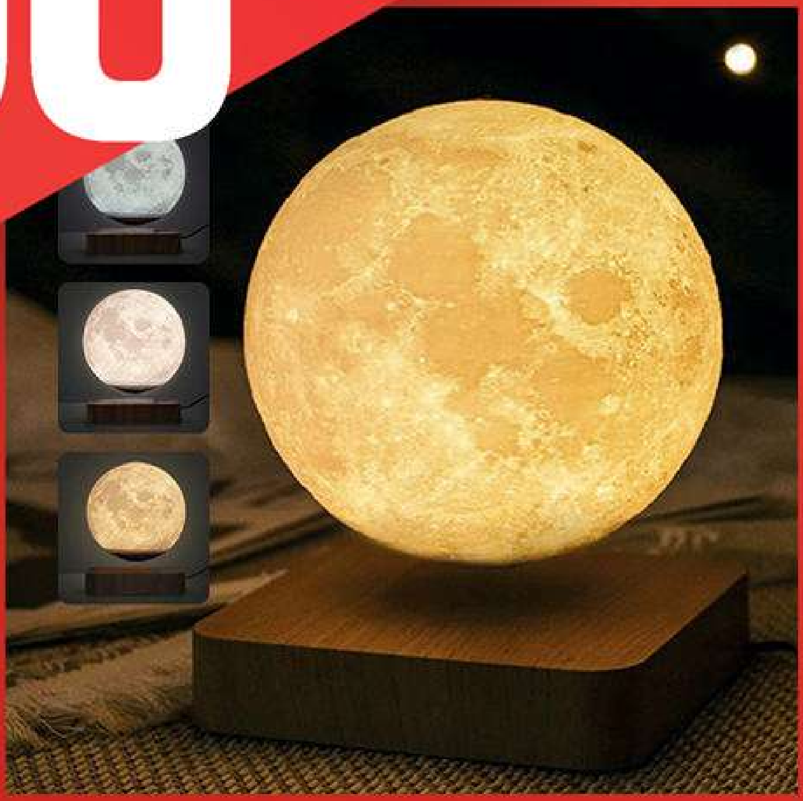
Win!

A LEVITATING MOON LAMP

WORTH OVER £180



This month we are giving you the chance to win one of two floating 3D Moon lamps. These celestial lamps use magnetic-levitation technology to float and spin in mid-air freely without any support or contact

For your chance to win, answer the following question:

How long does it take for the Moon to orbit Earth?

A: 2 DAYS B: 10 DAYS C: 27 DAYS

Enter online at **howitworksdaily.com** and two lucky entrants will win!

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BRAINDUMP

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Did you know? Wolves can eat nine kilograms of meat in one sitting

MEET THE EXPERTS

Who's answering your questions this month?

Jo Elphick
History and forensic science

Andy Extance
Chemistry, tech and science

Andrew May
Space, transport and science

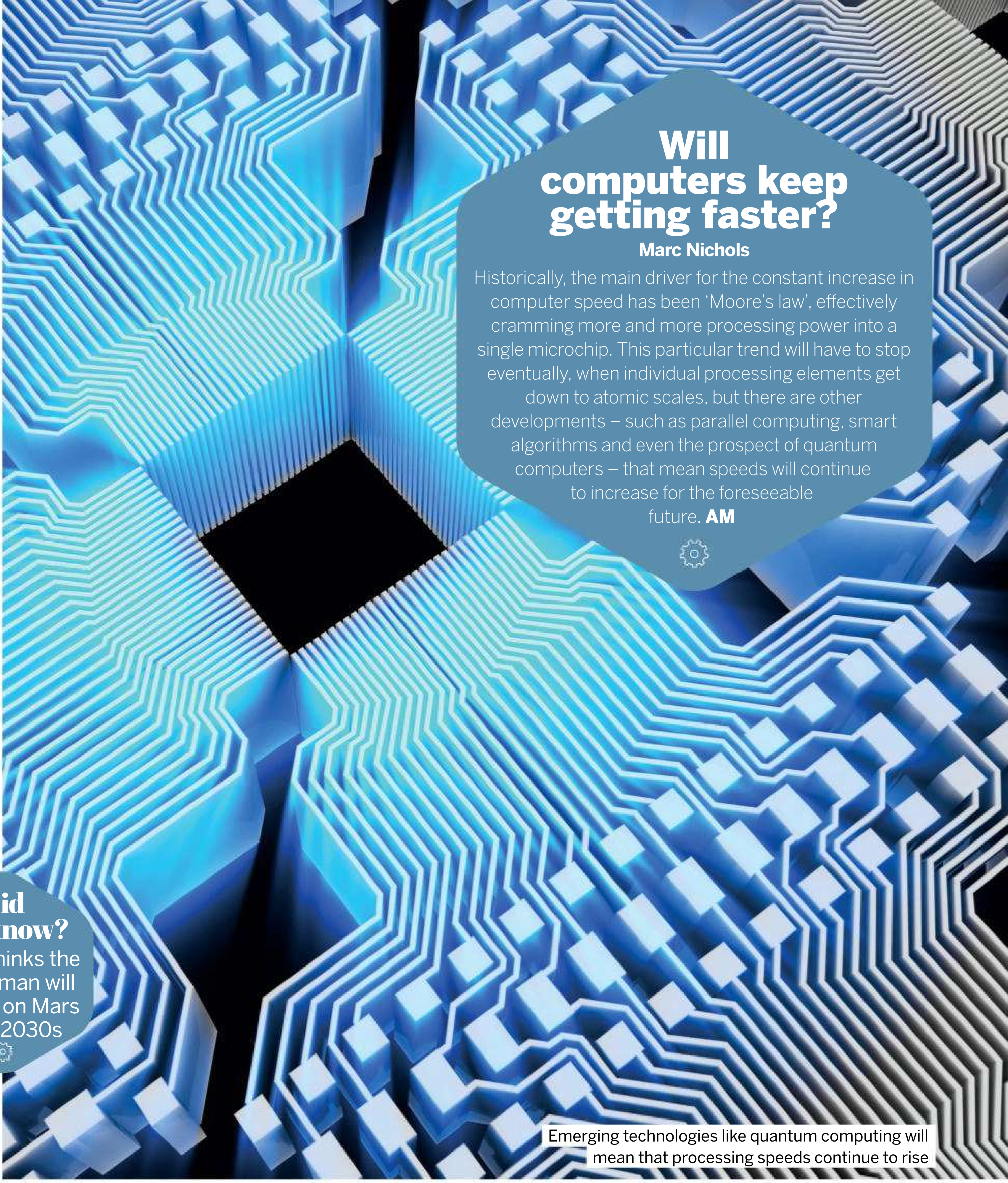
Victoria Williams
Animals, the environment and science

Why don't dogs act like wolves?

Riaz Hood

Humans first formed a relationship with wolves more than 30,000 years ago. That's the blink of an eye in normal evolutionary terms, but selective breeding has sped up the process. Over generations we've chosen the calmest, friendliest dogs, slowly breeding out the most wolfish behaviours. We've changed everything from where they live to what they eat. Dogs are also dependent on people, rather than a pack. They lack a wolf's problem-solving skills because they don't need them for survival. **VW**

Dogs have even evolved the ability to understand different human emotions



Will computers keep getting faster?

Marc Nichols

Historically, the main driver for the constant increase in computer speed has been 'Moore's law', effectively cramming more and more processing power into a single microchip. This particular trend will have to stop eventually, when individual processing elements get down to atomic scales, but there are other developments – such as parallel computing, smart algorithms and even the prospect of quantum computers – that mean speeds will continue to increase for the foreseeable future. **AM**

Emerging technologies like quantum computing will mean that processing speeds continue to rise

CAN PEOPLE REALLY 'WHISPER' TO ANIMALS?

Elora Mendoza

There's no evidence that 'animal whisperers' have any sort of psychic or telepathic abilities. However, it's possible to gauge how some animals are feeling – and to communicate with them – using body language. **VW**

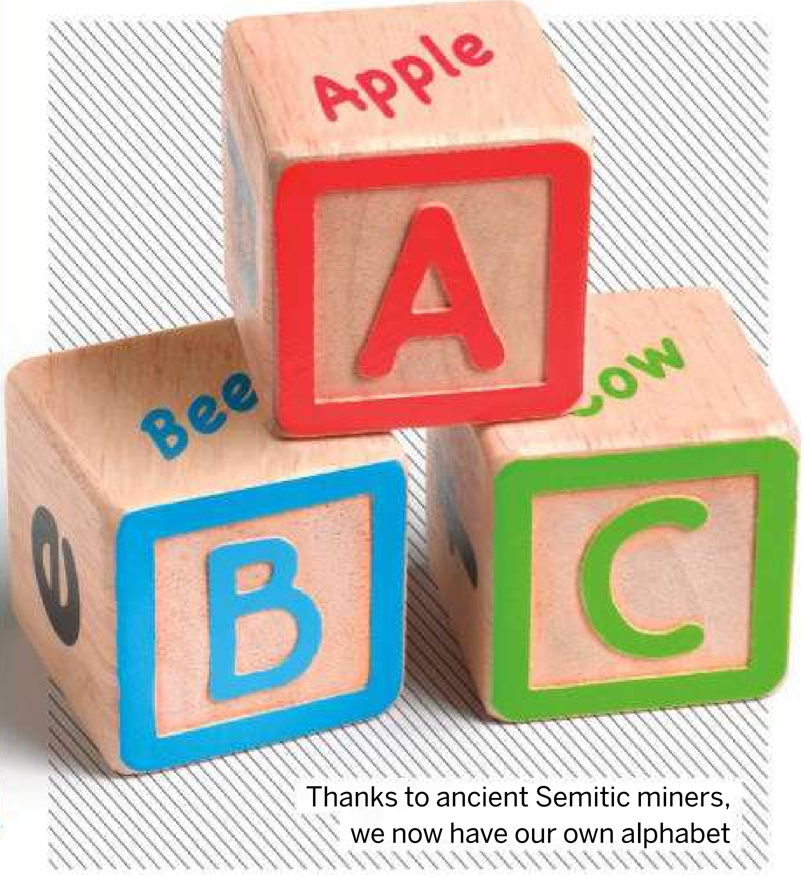
Did you know?

NASA thinks the first human will set foot on Mars in the 2030s

WHY DO ROCKETS LAUNCH IN STAGES?

Kaci Sullivan

A rocket has to lift its own weight as well as the payload it carries. This weight can be reduced by jettisoning stages when the fuel in them has been used up. **AM**



Thanks to ancient Semitic miners, we now have our own alphabet

Who invented the alphabet?

Jess O'Brian

4,000 years ago, a group of Semitic miners, who were sent by the Egyptian elite to look for turquoise, began scratching a simple form of writing into the rock walls. Rather than using complex images in the form of hieroglyphics as the Egyptians had done, the Middle Eastern miners created 22 simple symbols that could be combined in different ways to represent the words in their language – in other words, a basic alphabet. **JE**

© Getty / SpaceX

SEND YOUR QUESTIONS TO: HOW IT WORKS MAGAZINE @HOWITWORKSMAG HOWITWORKS@FUTURENET.COM HOWITWORKSMAG

WHAT IS THE WORLD'S SMELLIEST SUBSTANCE?

Heather Curran

This question isn't as subjective as it sounds because scientists can quantify the 'smelliness' of a chemical by how few molecules are needed for the human nose to detect it. In these terms, a group of sulphur compounds called thiols are way out in front. In fact, tiny amounts of methanethiol are deliberately added to natural gas, which is otherwise odourless, so people can detect gas leaks. But the smelliest thiol of all is thioacetone, which caused widespread fainting and vomiting when a small amount was accidentally released in the German city of Freiburg in 1889. **AM**

The odour from a test tube of thioacetone can cause nausea half a mile away

If you can be 'underwhelmed' and 'overwhelmed', can you simply be 'whelmed'?

Dennis Bailey

Yes, you can! The word 'whelm' is a verb meaning to submerge or engulf, and is generally used to denote somewhere between being underwhelmed and overwhelmed. It originally referred to boats being capsized, but today we tend to use it in relation to our emotions. **JE**

Did you know?
The best known thiol is 'rotten egg gas', hydrogen sulphide

WHY DO I GET BLISTERS IN MY MOUTH?

Rufus Tobias

A blister can occur on any soft area of the mouth, from the lip to the oesophagus, and there are many things that cause them. The most common way to get a blister is through injury. If you accidentally bite your lip or scratch your cheek while eating crispy food, you can easily cause a blister to form. They can also appear if the skin inside your mouth is irritated by strong toothpaste or mouthwash. Some acidic foods, such as oranges or pineapples, can trigger them, while others find that they get blisters if they are particularly stressed or generally feeling poorly. **JE**

Be careful when you take a bite. You could end up with a nasty blister

WHY DO SOME STARS TWINKLE IN DIFFERENT COLOURS?

Abdi Shah

Stars appear to twinkle because light from them is bent in different directions as it passes through the Earth's turbulent atmosphere. This bending effect, called refraction, acts differently on different colours of light, so it can sometimes look as if a star is changing colour. **AM**

HOW MANY ATOMS ARE THERE IN THE UNIVERSE?

Max Hall

Scientists have actually calculated that number: there are between 10^{78} and 10^{82} atoms in the universe. That's ten quadrillion vigintillion atoms to a hundred thousand quadrillion vigintillion atoms. That's an insane number, but unbelievably it's trumped by the number of possible legal and illegal moves in a game of chess, which is up to 10^{123}. **BB**

Why are roads covered in tarmac, not cement?

Juliet Phillips

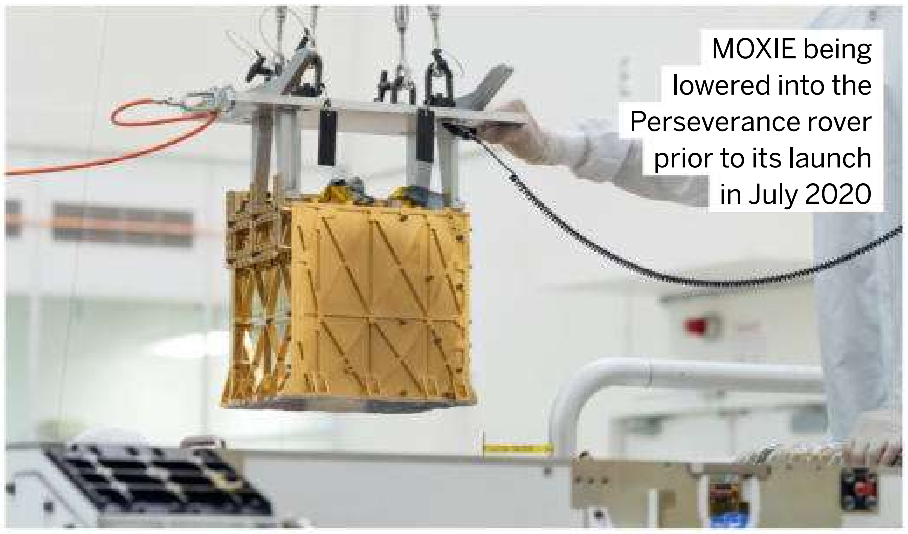
Actually, some roads are made of concrete. How many varies from place to place, from about one road in 20 to nearly half. There were 172 miles of concrete trunk roads in 2019 in the UK. You can usually tell because they are much noisier than tarmac. Concrete roads are slightly cheaper to maintain than tarmac, but driving on them feels much worse. You hear regular bumps because of how road builders lay them in sections that don't quite fit together perfectly. In the US, concrete roads sound better because road builders grind them to smooth them out. **AE**

Tarmac roads are more common than concrete ones in the UK

CAN OXYGEN BE SYNTHESISED ON MARS?

@iamtheredzone

NASA is currently testing the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) on Mars. It's designed to produce oxygen from the Martian atmosphere and works by taking in carbon dioxide, which makes up 96 per cent of the planet's gas, then splitting it electrochemically to create breathable oxygen and propellant for rockets and vehicles. However, this is just a stepping stone to a far-flung goal of having a human habitat on Mars. Martian habitats are still a huge technological leap to a self-sufficient Martian colony on a terraformed planet. This kind of advanced technology is several generations away from when we think the first human will set foot on Mars. **BB**



MOXIE being lowered into the Perseverance rover prior to its launch in July 2020

© Alamy / Getty / NASA

Chimps will take a close friend's side in a disagreement with other group members

Do any other animals have friends?

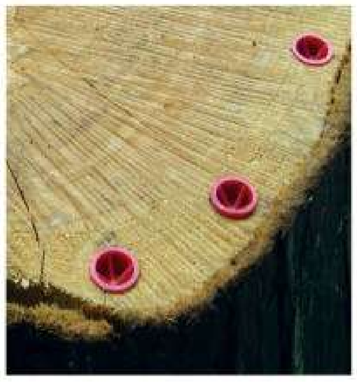
Connie Tierney

Lots of species are social and hang out in groups, but that doesn't necessarily mean they're pals. Relationships between animals are often transactional; groups form because there's safety in numbers, or because it's more efficient to hunt or collect food together. Scientists think it takes a lot of brainpower to form and maintain 'human-like' friendships based on affection. Species they think are capable of this type of relationship include primates, elephants, camelids (like camels and alpacas), cetaceans (like whales and dolphins), bats, bears, parrots and members of the horse family. **VW**

WHAT WAS THE FIRST INTERNET SEARCH ENGINE?

Millie Hayward

In 1990, a tool called Archie helped to search internet sites for files. JumpStation was the first world wide web search engine that behaved like modern search engines, launching in 1993. **AE**



WHAT ARE THE PLASTIC PLUGS YOU SOMETIMES SEE IN TREE STUMPS IN PARKS?

Leonard Parrish

They contain a herbicide called glyphosate, which travels through the stump to the roots. It prevents new growth – useful for invasive species – and causes the stump to rot away. Releasing the chemical directly into the stump minimises the risk of it harming wildlife or getting into waterways. **VW**

IS THERE A GAS THAT DOES THE OPPOSITE TO HELIUM IF YOU INHALE IT?

Bryan Cleveland

Helium makes your voice sound squeaky when you breathe it in because it's less dense than air – the same reason helium balloons float. That changes how your throat resonates when you speak. Gases denser than air, such as sulphur hexafluoride, instead change your throat's resonance to make your voice deeper. **AE**

Helium raises pitch

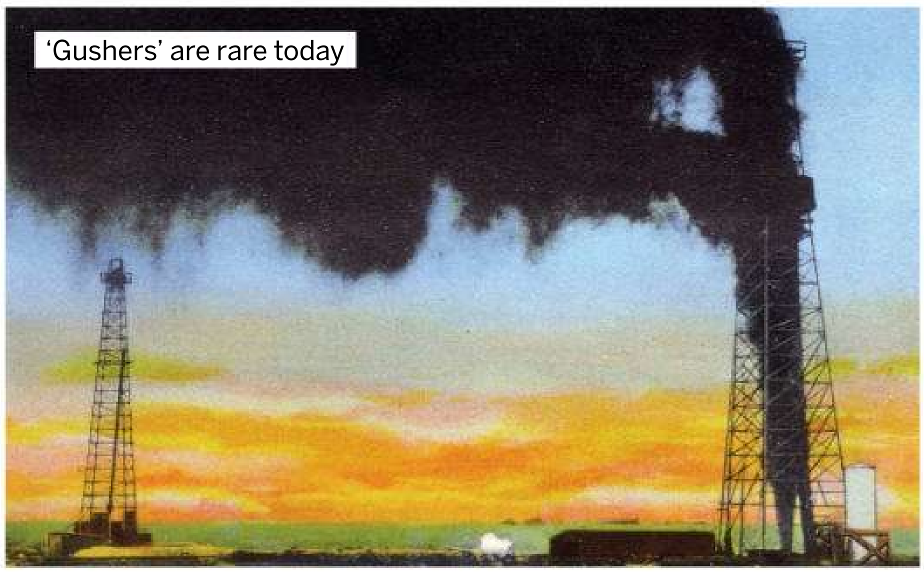
Did you know?

Hydrogen is the lightest gas and element

WHY DON'T YOU SEE OIL 'GUSHING' OUT OF OIL WELLS ANYMORE?

Annabel Cartwright

An oil well has a blowout, or 'gushes', when crude oil is accidentally released too quickly. Modern wells are equipped with pressure release systems which make incidents far less likely to occur. **JE**



'Gushers' are rare today

Clothes smell damp because of chemicals released by fabric-eating bacteria

What is the 'damp' smell you sometimes get on clothes?

Akeem Guest

It comes from chemicals produced by bacteria and fungi in your clothes. There are many such chemicals, but common ones are ammonia, hydrogen sulphide and short-chain fatty acids. Bacteria and fungi thrive in damp, warm places, growing and multiplying, forming new bacteria. They even eat the material in your clothes. The smell is what the bacteria and fungi release after munching on damp fabric, be it drying laundry, or clothes that have gotten wet. **AE**

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THE LIBRARY

The latest book releases for curious minds

THE SPACE BUSINESS
From Hotels in Orbit to Mining the Moon – How Private Enterprise is Transforming Space
Andrew May
HOT SCIENCE

THE SPACE BUSINESS

FROM HOTELS IN ORBIT TO MINING THE MOON

AUTHOR **ANDREW MAY**
PUBLISHER **ICON BOOKS**
PRICE **£8.99 / $16.95**
RELEASE **OUT NOW**

Now that Bezos, Musk and Branson have each put billions into private space ventures, sending wealthy tourists to the Kármán line in bespoke space planes and supplying NASA with rockets, the future's pretty clear to the rest of us Earth-bound mortals. We can all imagine a future where we, as a spacefaring species, will be able to jump on a sightseeing tour around Mars, or stay in a lunar resort with the family and don a spacesuit, exiting the dome habitat and visiting a UNESCO space heritage site like the 1969 Apollo 11 landing zone in the Sea of Tranquillity.

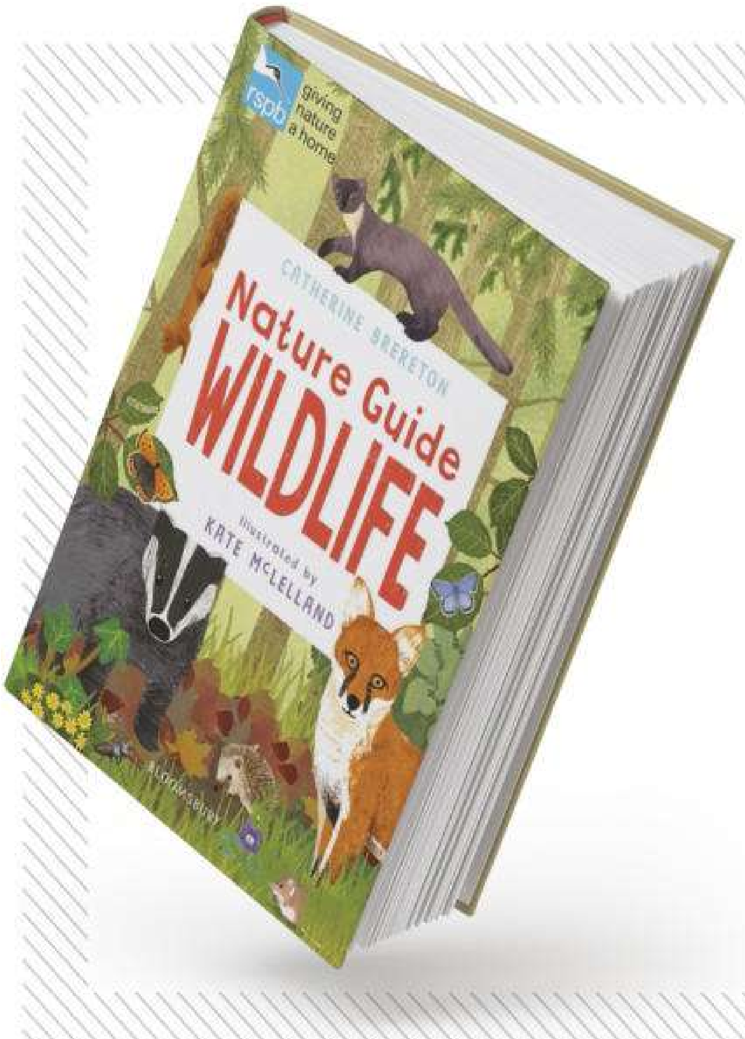
Or, if that's still too science fiction for you to swallow, low-orbit trips around Earth that are actually affordable to the average earner. Maybe some remote asteroid mining – and before you roll your eyes, that prospect is far from science fiction: we've already landed a probe on a speeding comet and have another spacecraft targeting giant space rocks in the asteroid belt at the time of writing.

The point that science writer and astronomer Dr Andrew May makes in *The Space Business* is that in just the last couple of decades, the private space industry has really taken off. It has required the ambition, resources and sheer graft of a select few talented individuals to really prove the concept that space isn't just for the state, but now the door is open to further private space ventures. Businesses can count the financial risk in the millions of dollars even for a small project, but the universe is their oyster. May walks the reader through the science of a myriad of space industries, many of which are analogous to what we have on Earth.

From extraterrestrial tourism, to heavy industries like lunar mining for rare minerals and rocket fuel, or harnessing the power of the Sun in enormous solar space arrays to solve the environmental disaster that is fossil-fuel energy generation on Earth: everything is covered. And don't forget the booming private industry surrounding those lucrative government space agency contacts.

As an established author with several non-fiction books to his name and a regular contributor to **How It Works**, this is May's area of expertise. *The Space Business* is easy to read, detailed and extremely well-researched – and fascinating to boot. It's a no-brainer for anyone who enjoys the odd Brian Cox documentary, and really for anyone who's interested in space, technology or business.

The Space Business is easy to read, detailed and extremely well-researched



RSPB NATURE GUIDE: WILDLIFE

TAKE A WALK ON THE WILD SIDE

AUTHOR **CATHERINE BRERETON**
ILLUSTRATOR **KATE MCLELLAND**
PUBLISHER **BLOOMSBURY**
PRICE **£8.99 / $15.35**
RELEASE **OUT NOW**

From woodlice and wildflowers to polecats and pike, this field guide covers all kinds of potential British wild encounters. There are more than 195 different animals, plants and other forms of wildlife to discover and identify within the pages of this guide. Its bitesize format and vibrant illustrations make this a great introduction to wildlife for any budding ecologist. This book is also a great transitional guide for a younger audience before they grow up and start using the RSPB's classic, more detailed field guides.

Along with being a useful guide to the wild outdoors, this book also includes species that you might find in your back garden and offers tips on how you can best help to protect them. For example, cutting hedgehog holes in your fence allows these small mammals to travel from garden to garden safely.

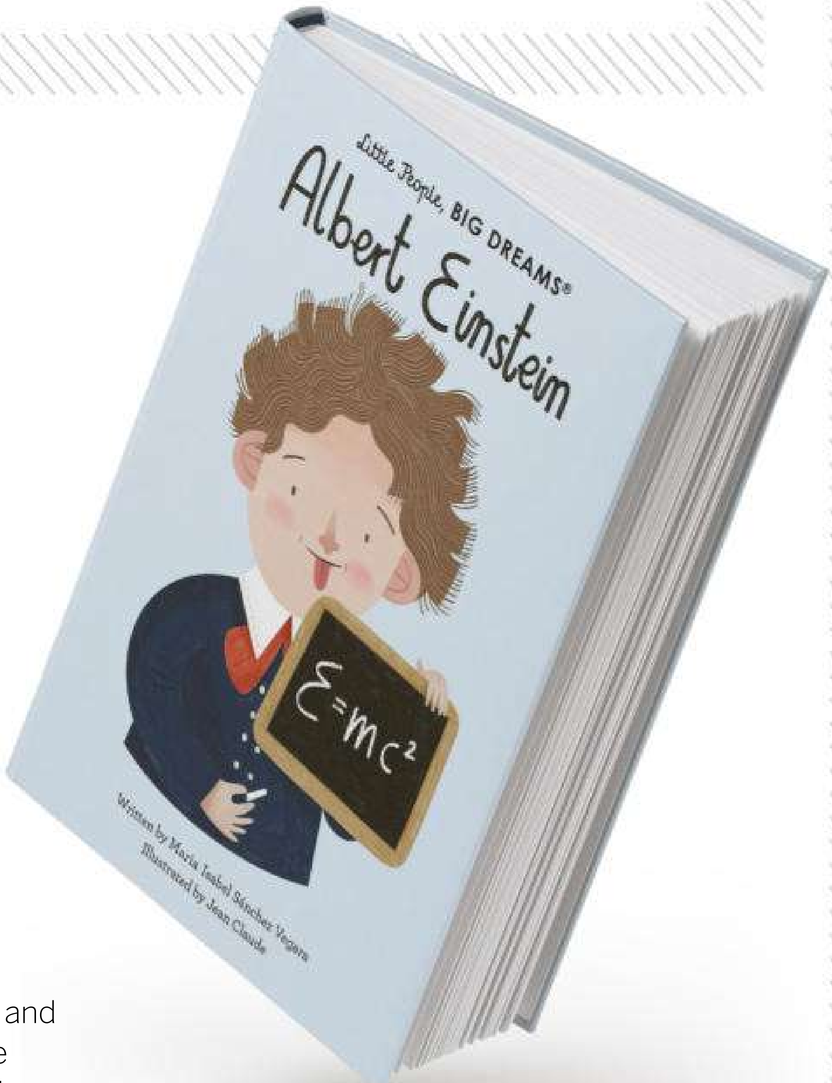
BUGS FOR BREAKFAST

HOW EATING INSECTS COULD HELP SAVE THE PLANET

AUTHOR **MARY BOONE**
PUBLISHER **CHICAGO REVIEW PRESS**
PRICE **£13.99 / $14.99**
RELEASE **OUT NOW**

Sustainability and the human impact on the environment have never before been so heavily discussed among politicians, business moguls and the general public. An example of these damaging impacts is our eating habits and the negative effects of food production and agriculture. But could farming insects offer a solution?

Boone serves up an alternative view on eating insects and reveals their nutritional value, their culinary prevalence around the world and how they may offer a sustainable source of food – you might be surprised to discover the amount of insect content that's already allowed in packaged food. This book challenges why we find insects so unappetising. Although you might not be convinced to switch out rump steaks for roasted crickets, it will certainly open the reader's mind to a more environmentally friendly potential



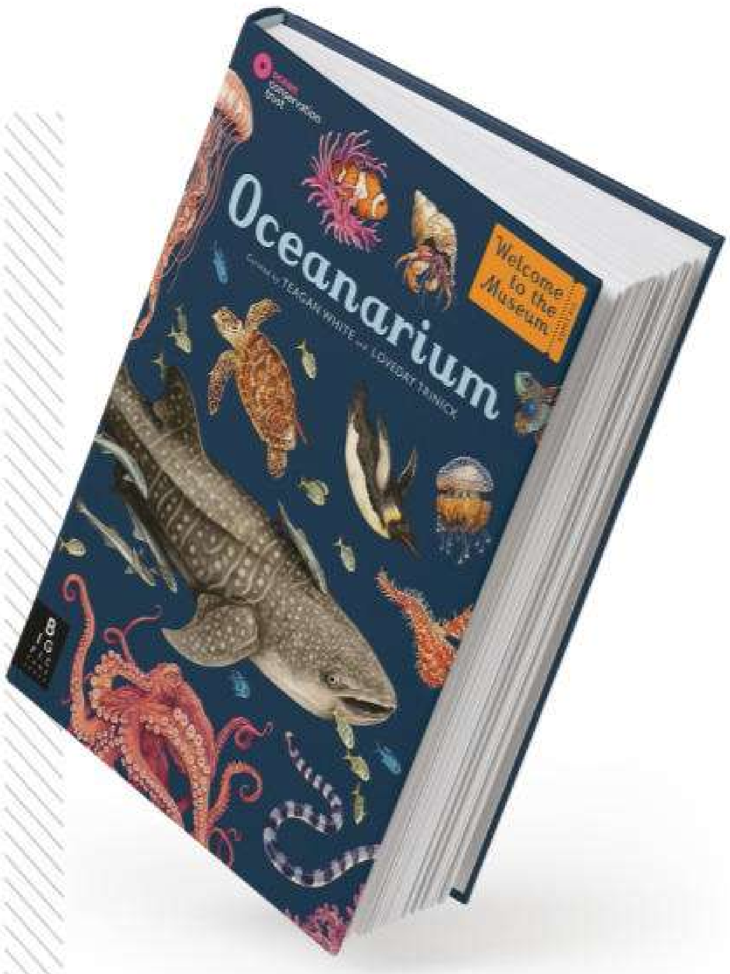
ALBERT EINSTEIN

LITTLE PEOPLE, BIG DREAMS

AUTHOR **MARIA ISABEL SANCHEZ VEGARA**
ILLUSTRATOR **JEAN CLAUDE**
PUBLISHER **FRANCES LINCOLN CHILDREN'S**
PRICE **£9.99 / $15.99**
RELEASE **OUT NOW**

This is the story of a quiet boy with a passion for science and maths. When he was just a teenager, Einstein wrote his first scientific paper, going on to become one of the world's most famous and inspirational scientists. As the 69th book in the 'Little People, Big Dreams' series, this biography dissects Einstein's life and turns it into an illustrated tale. It's written for children of primary school age, who benefit from picture books. While the events of the story are faster paced than the average children's book – in order to pack in the main events of a fascinating life – the warm illustrations that cover every page provide the perfect intervals. Claude captures Einstein's iconic look and expressions from childhood through to old age, with each chapter of his life cleverly illustrated in captivating detail.

As Vegara takes the reader smoothly through the most notable events of Einstein's life, she explains some of the scientist's most complex theories in a way that young readers can understand. From his successes and awards to facing wartime discrimination and his drive for acceptance and peace, this version of Einstein's life teaches children positive takeaway lessons. It inspires young readers to be curious about the world around them while always considering the bigger picture.



OCEANARIUM

WELCOME TO THE AQUATIC MUSEUM

AUTHOR **LOVEDAY TRINICK**
ILLUSTRATOR **TEAGAN WHITE**
PUBLISHER **BIG PICTURE PRESS**
PRICE **£25.00 / £37.99**
RELEASE **OUT NOW**

For anyone who loves the world hidden under the sea, *Oceanarium* is the book for you. Designed as a virtual museum, there are eight sections to explore: plankton, cnidaria, molluscs and echinoderms, arthropods, fish, mammals, birds and reptiles.

You will also learn about the importance of the ocean as a resource to humans. From the life the ocean supports at the surface to the multitude of ecosystems in the deepest reaches, you are welcomed in to explore this paper museum. Whichever section you stumble upon as you open up this book, the diverse shapes and details of ocean life are a marvel as seen through the informative annotated illustrations.

Author and marine biologist Trinick and illustrator White combine their talents to focus on the elaborate details of nature. Each sentence is carefully worded to incorporate a mesmerising fact or stat, with a 50/50 split of information and imagery beautifully complementing each other. It's a wonderful substitute for a visit to a real oceanarium.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		9	7			2		5
					3		4	7
2	7	6	4			1		
1					4		5	
9		5	8			4		6
6		4	5	9	2	8	7	
8	9			6	7			4
4				5	9		2	
			1		8		6	9

MEDIUM

1	7			2		4	8	
							6	7
9		2	6					5
2							1	8
	6		1		5			
3		9	2		7		4	
	3			9			2	4
6		4	3		2	8		
		7		6				

HARD

4		2		5				
			2		8	1		
3	8	7	1	6				
				2				
	2		5		1			3
							8	6
			9	8				2
		1				5	9	
9	5							

Word search

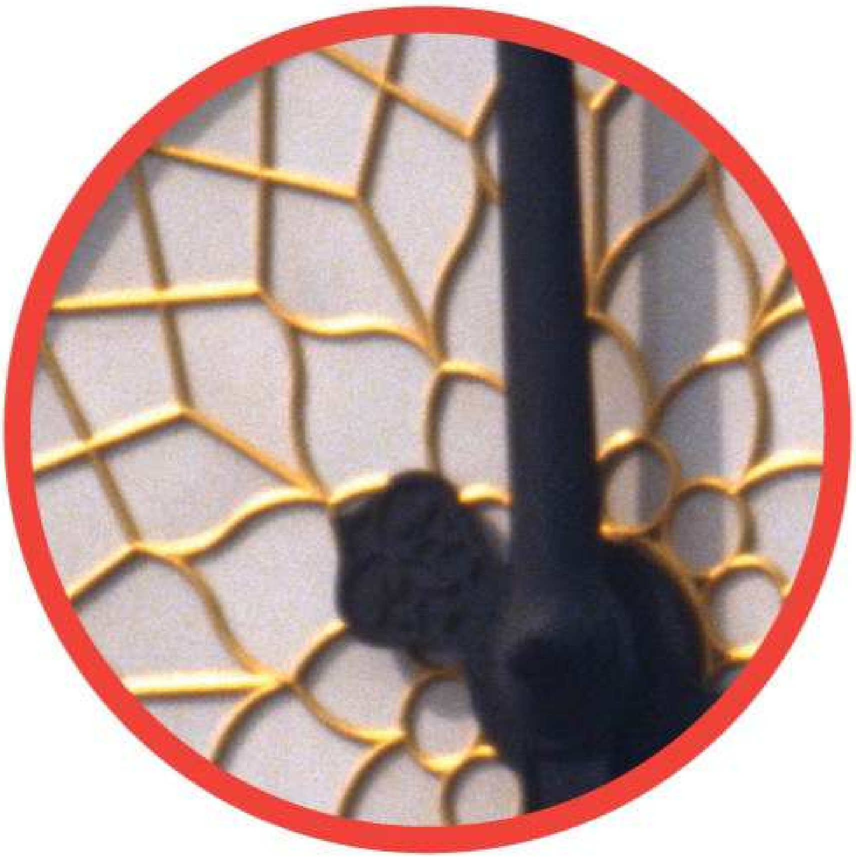
Find the following words

WEBB
TELESCOPE
KNIGHTS
CRYPTO
CAMEL
POISON
MAYAN
FLAT
GRAVITY
POLLUTED
BATH
RIG

L	A	Y	P	E	M	J	F	O	N	O	S	I	O	P
R	I	B	R	G	R	A	V	I	T	Y	I	E	N	O
S	Q	W	E	B	B	C	R	Y	I	M	K	N	I	L
T	E	F	E	S	C	A	E	R	V	O	P	U	R	L
F	L	O	I	T	Y	I	B	A	H	R	T	I	G	U
C	R	Y	P	T	O	E	L	P	U	X	E	F	H	T
G	A	R	U	N	A	T	H	E	C	K	L	J	E	E
V	I	M	K	N	O	N	C	L	M	O	E	R	I	D
E	T	A	E	Y	P	S	A	L	F	A	S	P	N	P
S	O	N	I	L	T	E	M	O	B	E	C	X	A	E
K	N	E	G	H	F	W	U	M	A	I	O	N	Y	T
B	E	T	G	I	R	C	L	K	T	H	P	J	A	O
F	W	I	P	E	V	Y	Q	U	H	O	E	K	M	B
O	N	X	U	B	A	H	T	C	R	Y	P	T	I	N
K	E	N	D	O	F	L	A	T	C	H	A	Z	T	E

What is it?

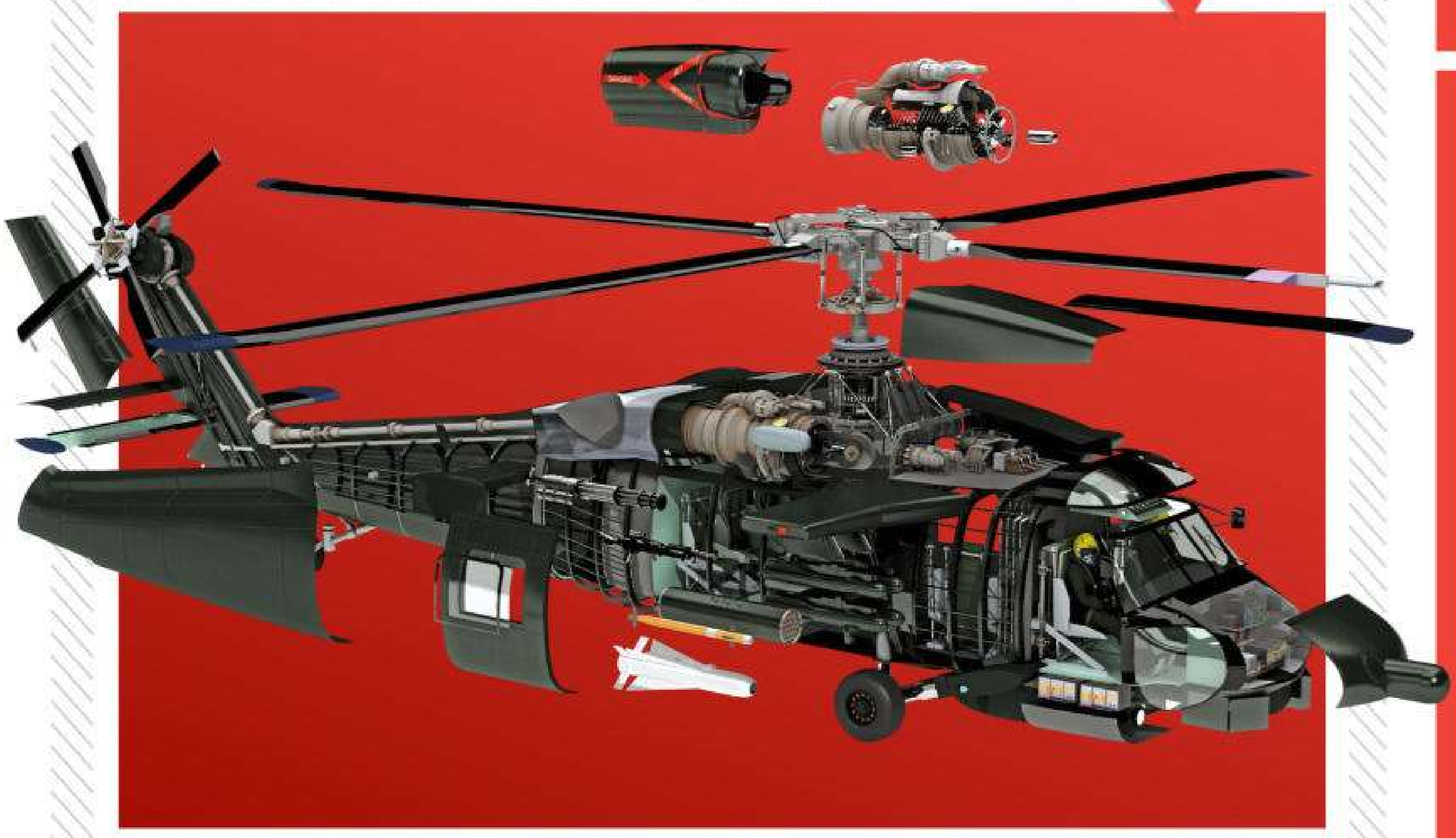
Hint: Arguably the world's most famous timepiece

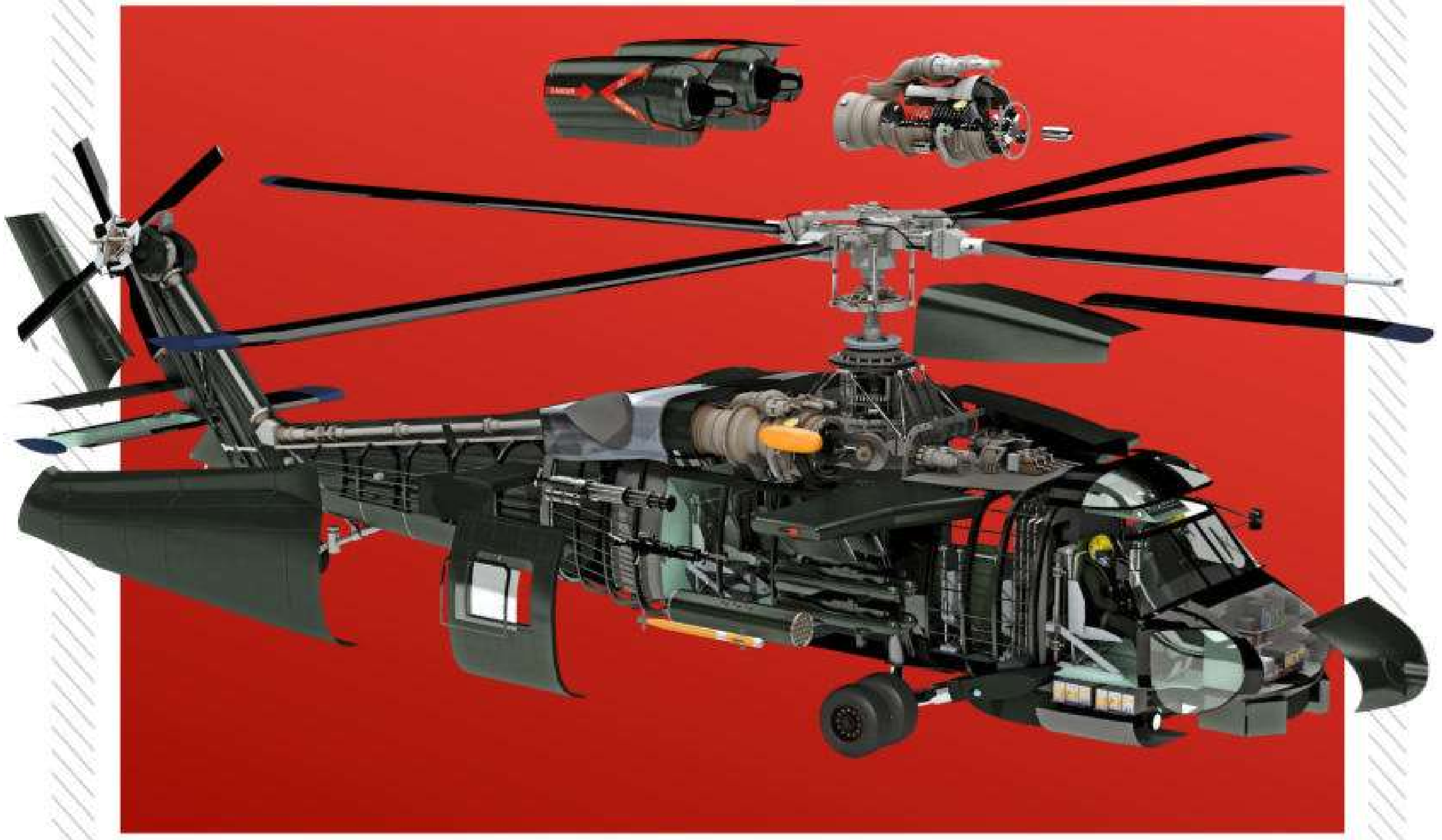


A

Spot the difference

See if you can find all six changes between the images below





QUICKFIRE QUESTIONS

Q1 Which of these is the most potent greenhouse gas?

○ Carbon dioxide
○ Methane
○ Nitrous oxide
○ Fluorinated gases

Q2 Which 1934 invention made driving at night a much safer prospect?

○ GPS
○ Streetlights
○ Cat's eyes
○ Road markings

Q3 Why do trees have bark?

○ To hold water in
○ As defence against insects
○ To reflect sunlight
○ To deflect woodcutter axes

Q4 Which of these is the most powerful computer

○ Cray-2
○ D-Wave Advantage
○ The Difference Engine
○ Macintosh 128K

Q5 What is infrared radiation also known as?

○ Visible light
○ Heat
○ X-rays
○ Sound

Q6 Approximately how many Earths would fit into the Sun?

○ 1,300
○ 130,000
○ 1.3 million
○ 133 million

Answers

Find the solutions to last issue's puzzle pages

Q1 ROSWELL, NEW MEXICO
Q2 A VIEW TO A KILL
Q3 JOSEPH STALIN
Q4 OHM
Q5 DECAYING VEGETATION
Q6 NINTENDO

What is it?

File
Edit
Format

PIXELS

Spot the difference

© Getty

CUT ICE WITH A WIRE

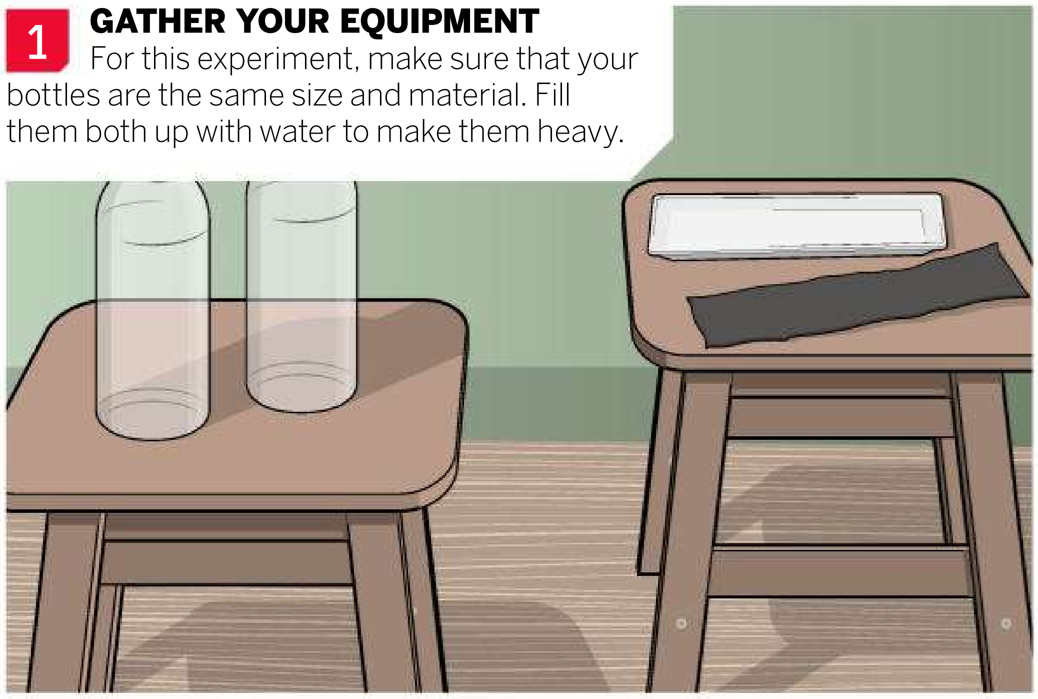
Watch as an ice cube divides under pressure before healing itself

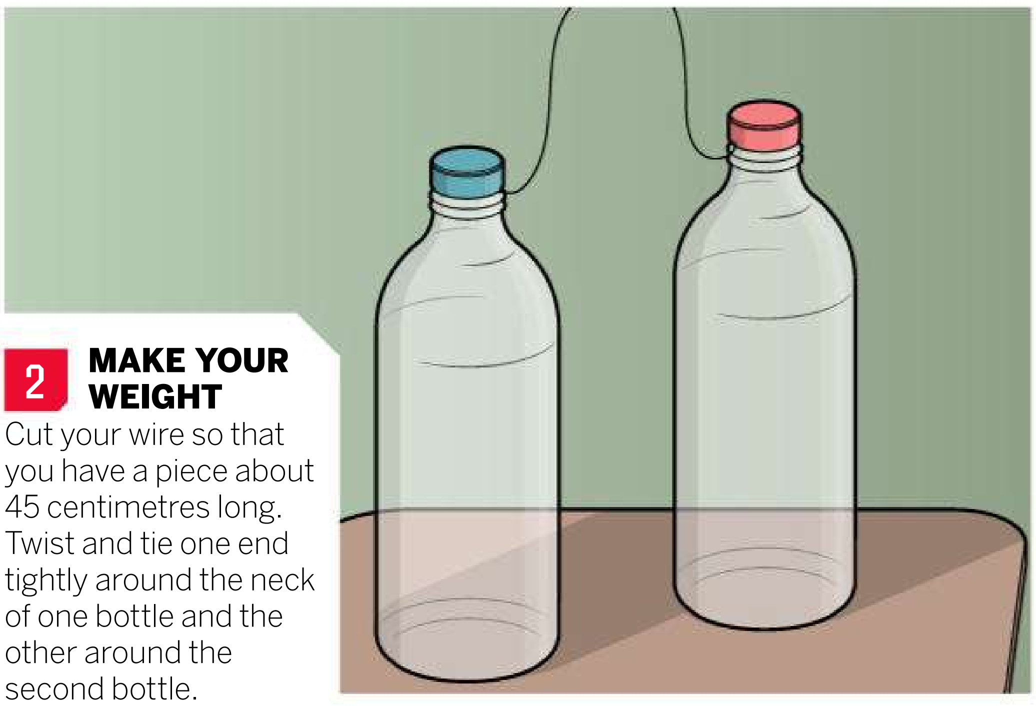
KIT LIST

- Two water bottles
- Two stools or chairs
- 45 centimetres of wire
- Tray
- Felt
- Ice cube

1 GATHER YOUR EQUIPMENT

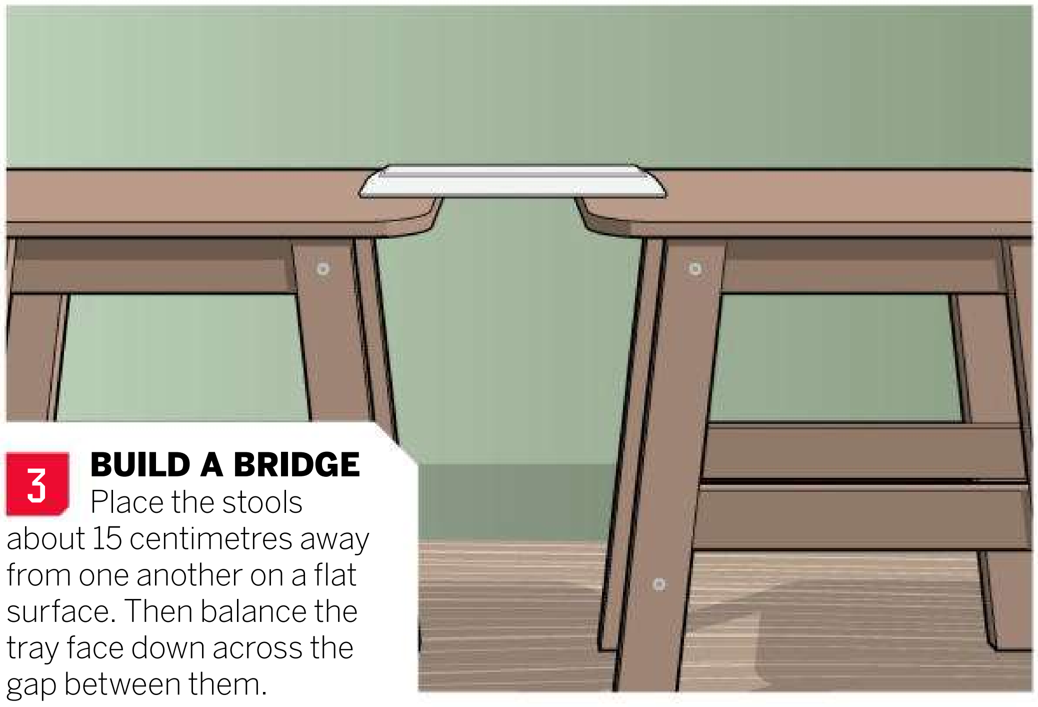
For this experiment, make sure that your bottles are the same size and material. Fill them both up with water to make them heavy.





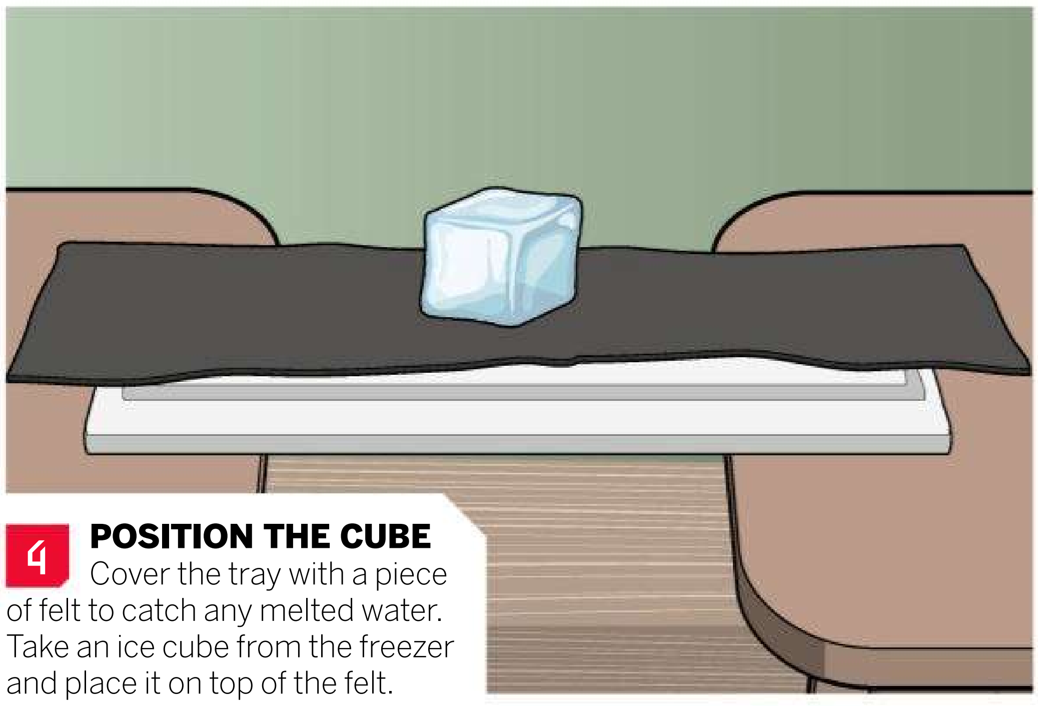
2 MAKE YOUR WEIGHT

Cut your wire so that you have a piece about 45 centimetres long. Twist and tie one end tightly around the neck of one bottle and the other around the second bottle.



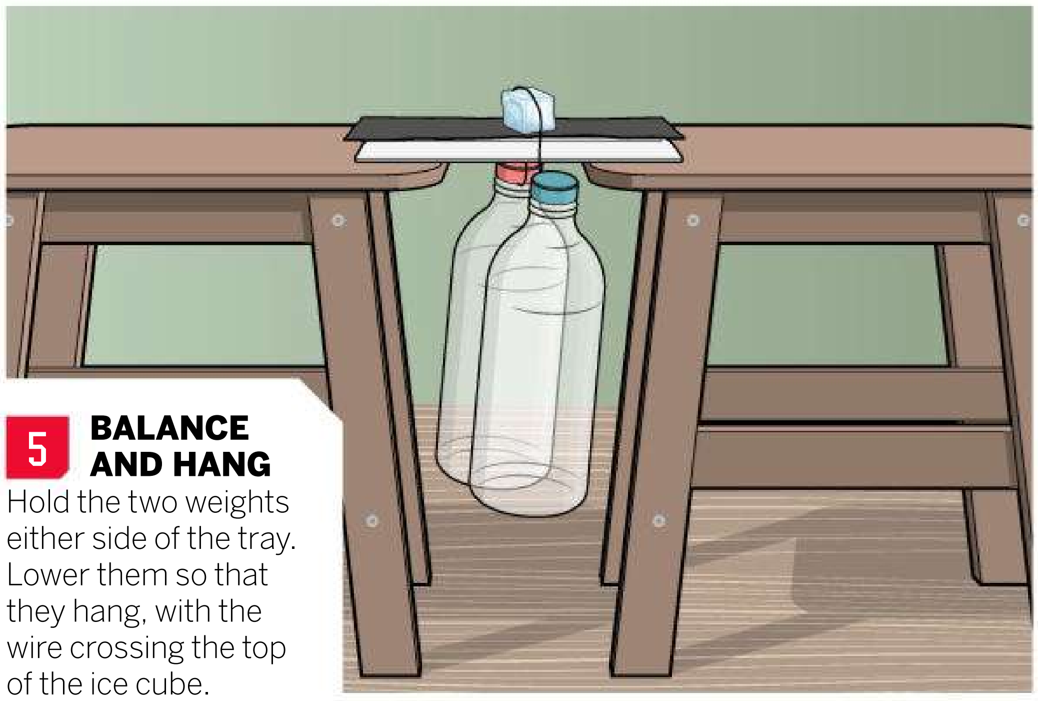
3 BUILD A BRIDGE

Place the stools about 15 centimetres away from one another on a flat surface. Then balance the tray face down across the gap between them.



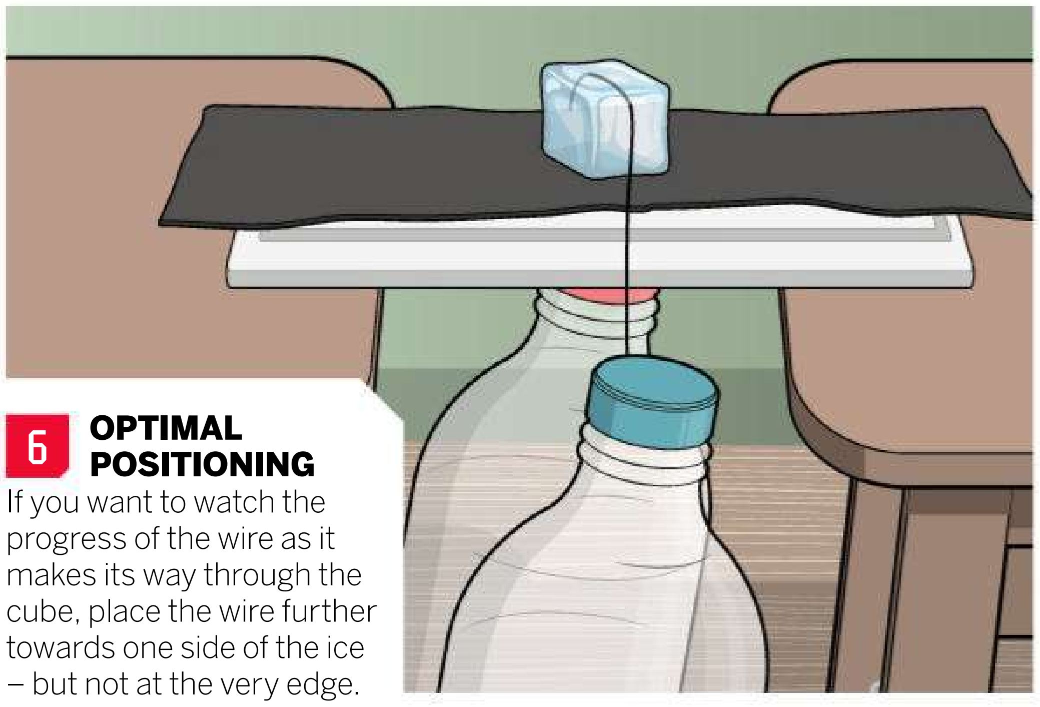
4 POSITION THE CUBE

Cover the tray with a piece of felt to catch any melted water. Take an ice cube from the freezer and place it on top of the felt.



5 BALANCE AND HANG

Hold the two weights either side of the tray. Lower them so that they hang, with the wire crossing the top of the ice cube.



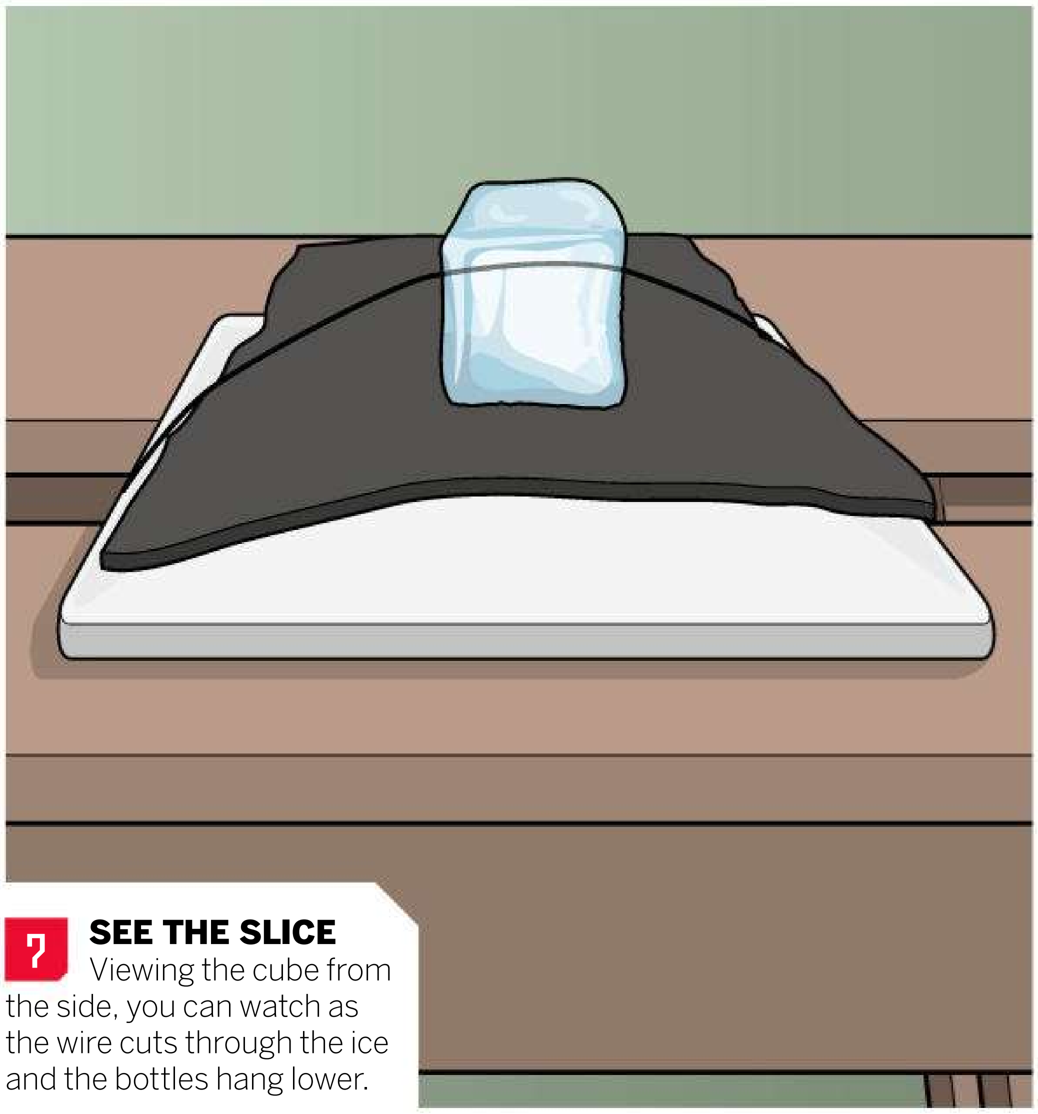
6 OPTIMAL POSITIONING

If you want to watch the progress of the wire as it makes its way through the cube, place the wire further towards one side of the ice – but not at the very edge.

SEND YOUR IDEAS TO: HOW IT WORKS MAGAZINE @HOWITWORKSMAG @HOWITWORKS@FUTURENET.COM @HOWITWORKSMAG

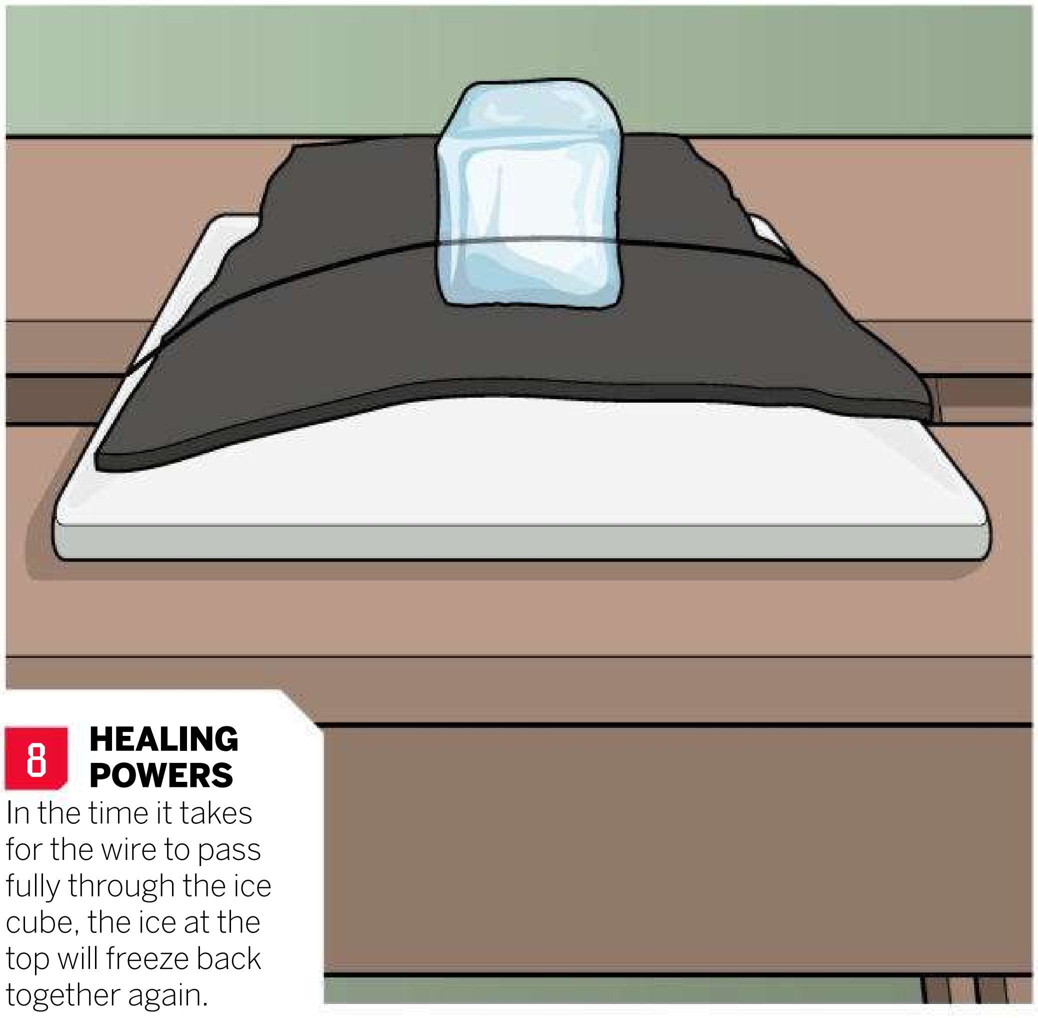
NEXT ISSUE
DEFY GRAVITY WITH BALANCING FORKS

DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you



7 SEE THE SLICE

Viewing the cube from the side, you can watch as the wire cuts through the ice and the bottles hang lower.



8 HEALING POWERS

In the time it takes for the wire to pass fully through the ice cube, the ice at the top will freeze back together again.

SUMMARY

The ice cube melts where the wire presses down on it due to the applied pressure. As the wire is pulled downwards by the weight of the water bottles, it creates localised pressure and localised melting. When this pressure is removed, after the wire has passed below the melted parts of the ice cube, it refreezes in a process called regelation. This happens because only a small section has been melted into denser water. When the pressure is gone, the temperature of the surrounding ice makes the water freeze back into its solid form.

In nature, this melting process can be observed in glaciers. Just as the weight of the bottles increases the pressure on the ice cube, glacial ice experiences the highest pressures at the bottom of the block. This is due to the accumulative weight of the ice above. As the bottom of glaciers melt under pressure, the entire block of ice can become mobile and slide across the surface below.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

SEND YOUR QUESTIONS OR COMMENTS TO: HOW IT WORKS MAGAZINE @HOWITWORKSMAG @HOWITWORKS@FUTURENET.COM @HOWITWORKSMAG

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH!

THE SPACE BUSINESS

20th-century space exploration may have belonged to state-funded giants like NASA, but with hotels in orbit to mining the Moon, today private enterprise is setting the template for the future

NIGHT-TIME TALKING

Dear **HIW**,
Why do I sleep talk?
P.S. I read my first **HIW** magazine at seven years old. I love **HIW**.
Jason Thomas in Australia (11 years old)

LETTER of the MONTH

Sleep talking is common in people of all ages, though it seems to affect fewer adults than children. Doctors don't know too much about the causes of sleep talking, but it can be more likely to occur when you're excited or worried. It can range from full conversational speech to mumbling and nonsensical words. Most of the time, episodes will only last for 30 seconds or less. While talking in your sleep can be linked to the dreams you are having, this isn't always the case.

About five per cent of adults sleep talk

Scientists have discovered that sleep talking can take place in all stages of sleep.

Regular sleep talking may be genetic, but if it only occurs as a one-off, this could be caused by other factors. These include sickness, stress and sleep deprivation. Making sure you take time to relax before bed can reduce your chances of chatting.

CAFFEINE IMMUNITY

Dear **HIW**,
I used to drink huge amounts of tea and coffee. It never stopped me sleeping though. I used to sleep like a log with it. How did my body do it?
Stephen Conn

Caffeine affects each person differently. For some, it can be frustrating when a cup of coffee keeps them up all night, while others miss the boost of energy that others experience. If caffeine doesn't create stimulating effects, this may be due to your genetics. Around ten per cent of people carry a gene that makes them hyposensitive to caffeine. This means that they can drink lots of tea and coffee, like yourself, with little effect.

It takes around 45 minutes for your body to absorb the caffeine in a cup of coffee. Caffeine molecules bind to receptors on the ends of nerve cells in the brain to block the neurotransmitter adenosine. Adenosine usually encourages sleep, but caffeine prevents this. In your case, these receptors may be less effective at binding to the caffeine.

Some people build up a tolerance to caffeine

ZIP LINE TESTING

Dear **HIW**,
I went on a zip line for the first time, which was so scary but amazing. I had never been on one before, but my friend has been on a few. It made me wonder when the first zip lines were made. Are they relatively new?
Annabel Sword

Zip lines have been used through history as a method of transport across mountainous areas, for example in the Nujiang Valley of China. This remote area once had many zip lines that people used to cross its rivers. Many have now been replaced with bridges as safer, more permanent methods.

The first zip line as a form of entertainment dates back to 1739, but modern zip lines rose in popularity in the 1970s. Biologists used them as tools to suspend themselves above jungle canopies and research the environment around them, but the design was soon picked up by entrepreneurs and converted to rides for adrenaline seekers.

In the US there are over 400 commercial zip lines

NEXT ISSUE

ISSUE 159

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Vatican City is smaller than New York's Central Park

THE WORLD'S SMALLEST NATION

Dear **HIW**,
What is the smallest country in the world and how many people live there?
Louise McCombie

Although its name has the word 'city' in it, the smallest country in the world, based on landmass, is the Vatican City. Landlocked by Italy with a two-mile border surrounding it, this country is home to 800 people. The country with the smallest population is the Pitcairn Islands. The population has varied between 40 and 60 people over recent years. It's made up of four islands, located halfway between Peru and New Zealand.

Tortoises usually live in hot, dry environments

TURTLE OR TORTOISE?

Dear **HIW**,
I always hear people get confused between turtles and tortoises, as they do look similar. Are they related? Although they look similar, they seem to have very different lives.
Jonah Booth

Thank you for your question, Jonah. All tortoises are turtles, but not all turtles are tortoises. This is because the term 'turtle' can be used to refer to all species under the order Testudines, or Chelonia. These species are reptiles with bodies in a bony shell. The easiest way to differentiate between turtles and tortoises is to know that tortoises live only on land. However, to add to the confusion, some turtles – such as box turtles and wood turtles – also live on land.

WE ASKED YOU

This month on Instagram, we asked you: Which of the world's famous buildings and landmarks do you think is the most impressive?

@SAMMY.GLANFIELD
El Capitan

TIRA.__.MISU
I think it's the Great Wall of China because of how long it is!

@MAIA_H3
Colosseum

@HAMID.BAGHERNIA
St Basil's Cathedral in Russia

@JONESY_RHYS06
Sagrada Família as it has been under construction for so long and is so intricately detailed

@AESTHETICALLY_AJ
Stonehenge is fascinating, with new information always being discovered

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FAST FACTS

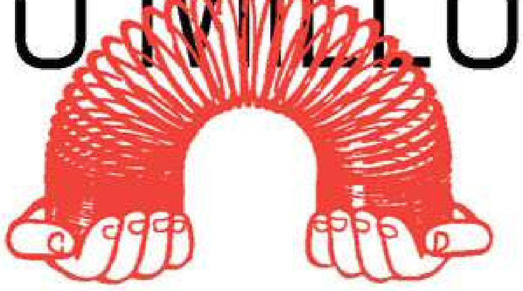
Amazing trivia that will blow your mind

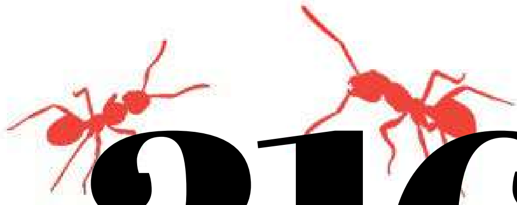
40 MINUTES

Some sloths can hold their breath over 15 minutes longer than the human world record

3,735,219.15 MILES

All the Slinkies ever made would wrap around the world 150 times





316 MILLION TONNES

All the ants on Earth weigh about the same as all the humans

15 MILLION DEGREES CELSIUS

A pinhead of the Sun's core is hot enough to kill a person 100 miles away

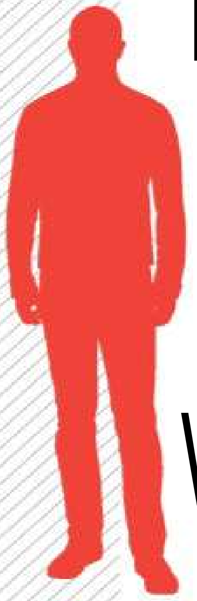
1944

It's been less than 80 years since the last English woman was tried for witchcraft

THE UK HAS MORE TORNADOES PER SQUARE MILE THAN ANY OTHER COUNTRY

Q

Denmark banned this letter in 1872



THE HUMAN BODY GLOWS WITH A TINY AMOUNT OF VISIBLE LIGHT

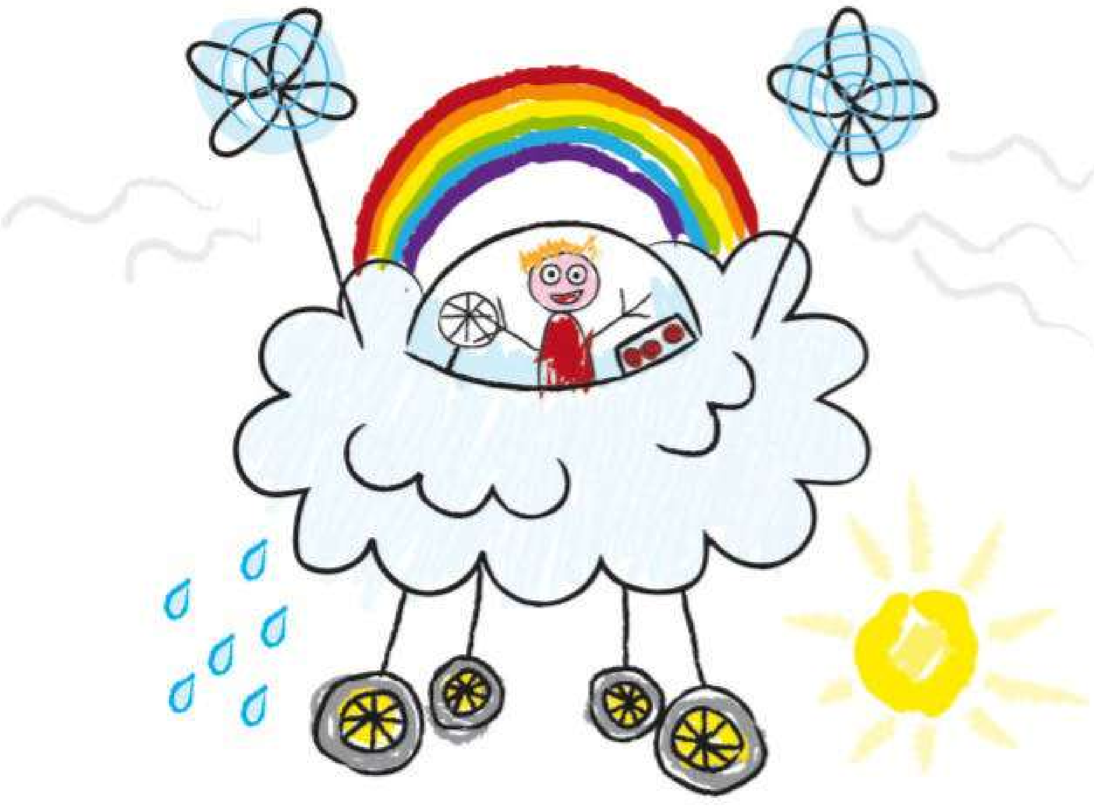
1928

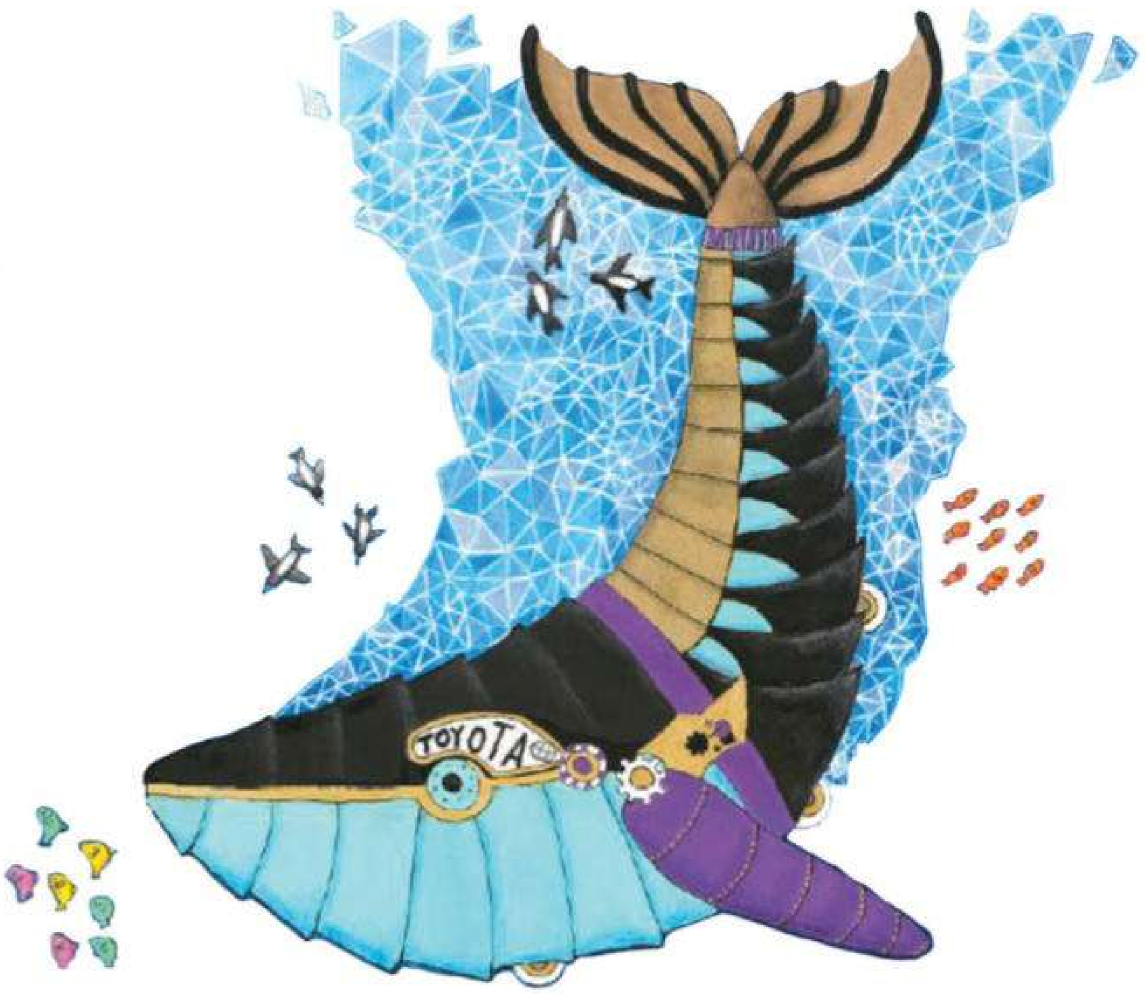
In this year, the UK, US and Germany signed a treaty to end all war

All British passports were written in French until 1858

42 MINUTES AND 12 SECONDS

It would take less than an hour for you to fall through a hole to the other side of Earth





2022 TOYOTA DREAM CAR ART CONTEST

Entries are open for the 2022 Dream Car Art Contest

Great prizes to be won by designing a car for the future
in Toyota's Dream Car Art Contest

Toyota is giving children a great opportunity to use creativity, imagination and drawing skills to explore what the future of mobility might look like.

Prizes include winning an iPad or a Samsung tablet, plus a Toyota goody bag. Their work will be entered in the competition's global final.

To enter and for full details please visit:
www.Toyota.co.uk/dreamcar

Entries close: 31st December 2021

TOYOTA DREAM CAR
ART CONTEST

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- Push Fit

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FORD MUSTANG GT

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6+

QUICKBUILD
Stickers Included
Rolling Wheels
Pre-Coloured
Push Fit
ACTUAL SIZE
Ford Mustang GT
Designed and made in the UK
www.airfix.com/quickbuild

Ford Mustang GT
Build an Iconic Model

The sixth generation Ford Mustang (S550) is the current iteration of the Mustang pony car manufactured by Ford. In departure from prior Mustang models, the sixth generation Mustang includes fully independent rear suspension on all models, as well as an optional 2.3L EcoBoost turbocharged and direct injected four-cylinder engine. The new Mustang was introduced as a 2015 model year vehicle, marking the fiftieth anniversary of the Ford Mustang, which was revealed as a 1965 model year vehicle on April 17, 1964. The sixth generation is also the first Ford Mustang to be marketed and sold globally, and represented the first time that factory right hand drive Mustangs were produced in addition to the left hand drive models.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. Recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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